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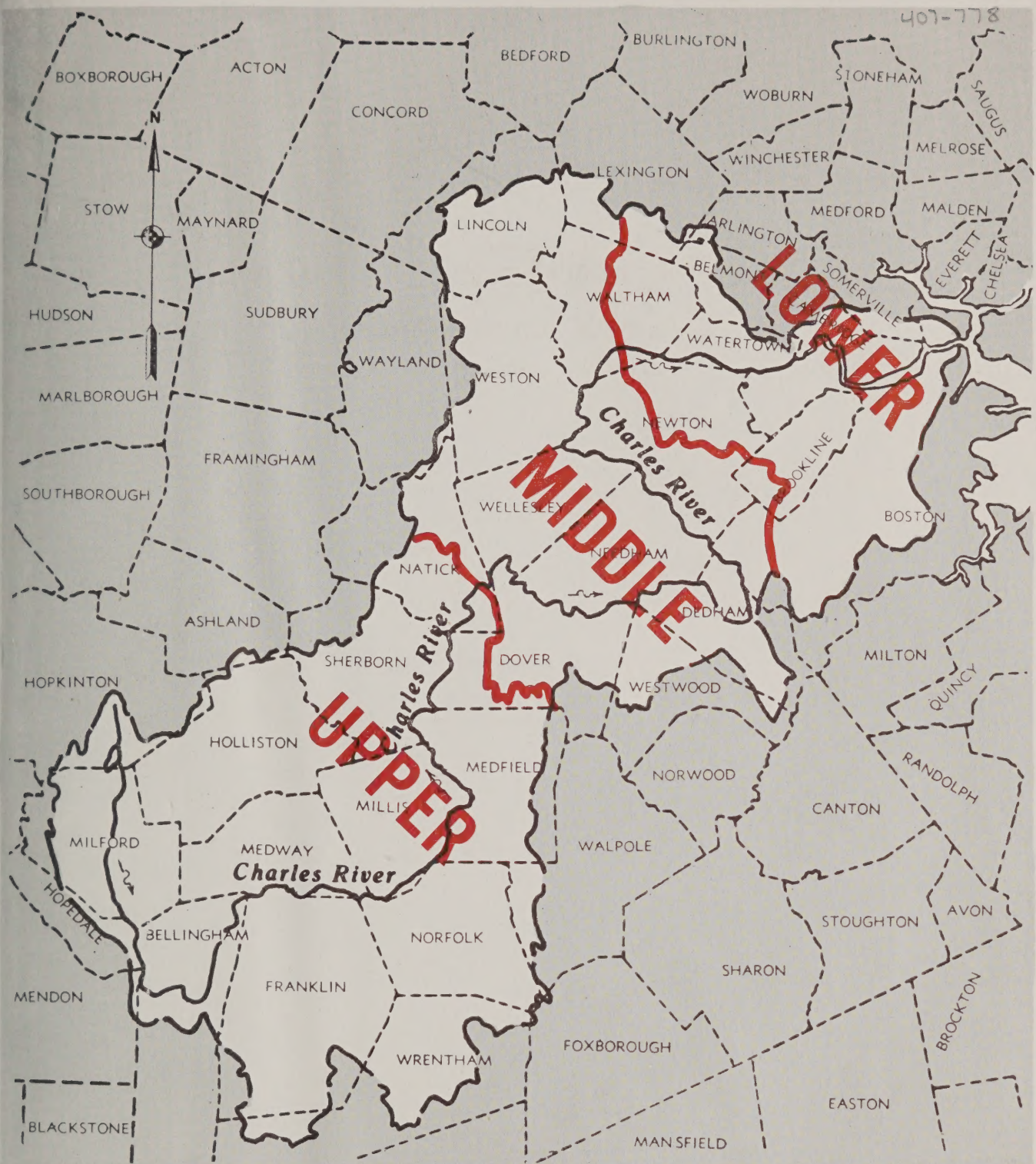
APPENDICES

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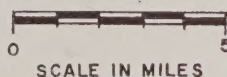
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DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION • CORPS OF ENGINEERS
WALTHAM, MASS. 02154



CHARLES RIVER WATERSHED

NEW ENGLAND DIVISION, CORPS OF ENGINEERS



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WATER RESOURCES INVESTIGATION

CHARLES RIVER STUDY

APPENDIX A

CONDUCT OF STUDY

PREPARED BY

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASSACHUSETTS

DECEMBER 1971

APPENDIX A

CONDUCT OF THE STUDY

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APPENDIX A

CONDUCT OF THE STUDY

1. INTRODUCTION

This final report is the presentation of the results of a five year study on the Charles River, authorized by a resolution of the Committee on Public Works of the House of Representatives, adopted 24 June 1965.

Pursuant to this resolution, the Division Engineer published a Plan of Survey, dated 30 August 1967, aimed at developing a comprehensive plan for water and related land resources for the Charles River watershed, indicating orientation, direction and coordination as well as inter-relationships and missions among the participants in the study.

An interim report on the lower Charles downstream of Moody Street in Waltham, completed May 1968, was published as House Document No. 370, 90th Congress. That report recommended the construction of a new dam for flood control and navigation, impounding the Charles River Basin at Warren Avenue, Boston. This final report considers problems of the Lower Charles River watershed, not presented in the Interim Report, and findings and recommendations of a study of the upper watershed, upstream of Moody Street in Waltham.

In the course of the investigation, measures were taken to provide for fullest practical participation by agencies of Federal and State government by municipalities and towns and by civic groups and interested individuals. Several major approaches were followed. A Coordinating Committee guided and coordinated technical aspects of plan formulation, formal and informal public meetings were held, and a Citizen' Advisory Committee and other citizen groups assisted in the formulation of a plan to meet the needs and desires of the public.

The following paragraphs are intended to describe briefly, the conduct of the study and the efforts of the participating Coordinating Committee.

2. COORDINATING COMMITTEE

Assistance and guidance in developing the comprehensive watershed plan for the Charles River was provided by the Coordinating Committee. As regional representative of the Chief of Engineers, the Division Engineer of the New England Division, U. S. Army Corps of Engineers served as Chairman of the Committee which was comprised of representatives of each of the participating Federal and State agencies. (See Table 1 and Figure 1.)

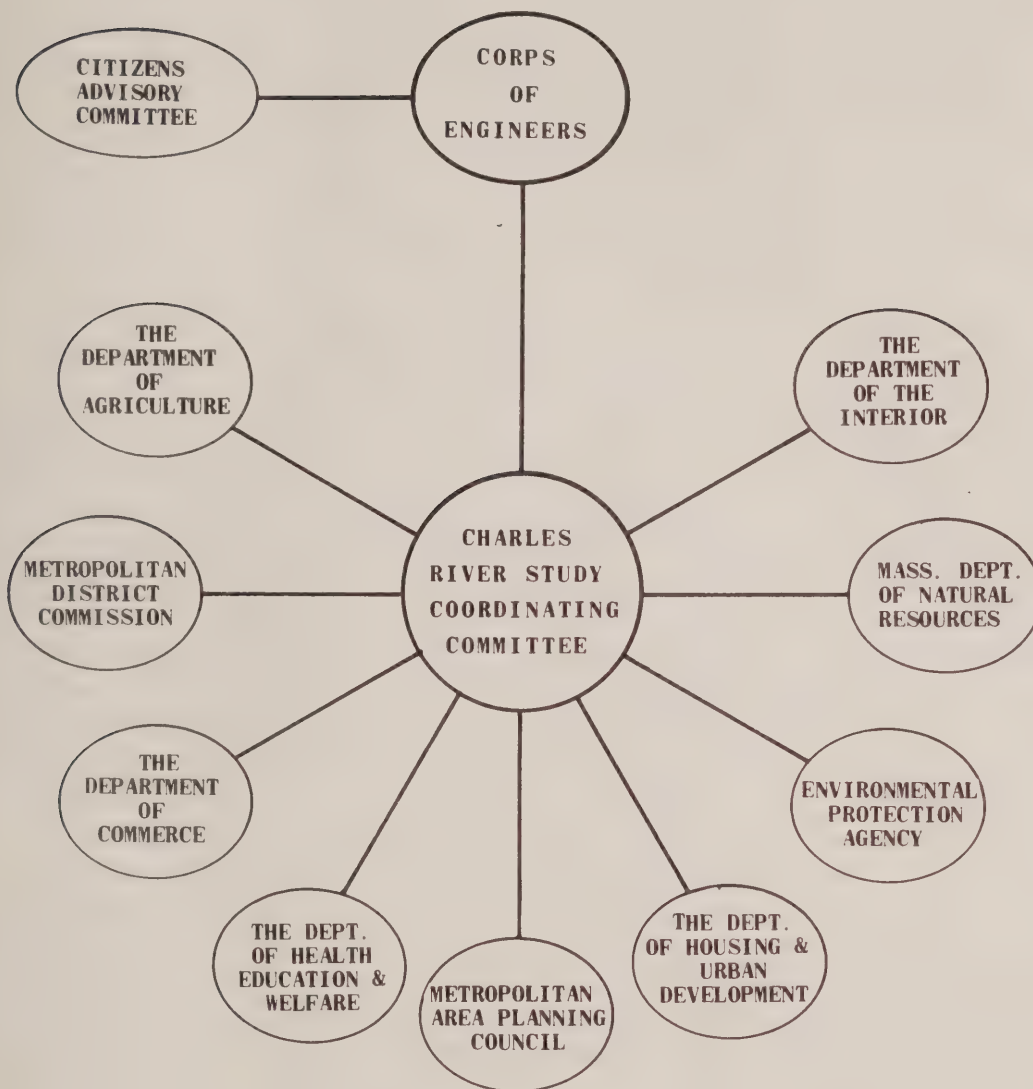
TABLE NO. 1

MEMBERSHIP

CHARLES RIVER STUDY COORDINATING COMMITTEE

<u>Agency Represented</u>	<u>Committee Member</u>	<u>Dates of Service</u>
Department of Agriculture	Dr. Benjamin Isgur	Nov 66 - Present
Department of the Army	Col Remi O. Renier Col F. R. Day Col Frank P. Bane	Nov 66 - Aug 68 Aug 68 - Sep 68 Sep 68 - Present
Department of Commerce	Edwin W. Webber Erwin Hannum Donald R. Baker	Feb 67 - Mar 69 Mar 69 - Mar 71 Mar 71 - Present
Environmental Protection Agency	Bart Hague	Dec 70 - Present
Department of the Interior	Mark Abelson	Nov 66 - Present
Department of Health, Education & Welfare	Frank Tetzlaff Floyd B. Taylor	Nov 66 - Jan 70 Jan 70 - Present
Department of Housing & Urban Development	Frank A. Batstone S. William Greene	Nov 66 - Mar 71 Mar 71 - Present
Massachusetts Department of Natural Resources	Robert L. Yasi Arthur W. Brownell	Nov 66 - Jan 69 Jan 69 - Present
Metropolitan Area Planning Council	Robert Davidson Richard M. Doherty	Oct 67 - Apr 70 Apr 70 - Present
Metropolitan District Commission	Howard Whitmore John W. Sears	Nov 66 - Feb 70 Feb 70 - Present

CHARLES RIVER STUDY COORDINATION



3. CITIZENS ADVISORY COMMITTEE

A Citizens Advisory Committee was formed 1 May 1967. Its members represent many and diverse interests. The Committee provided valuable information on specific desires, problems, and conflicts existing in the watershed. Membership on the Committee was limited to persons having active business, professional, and civic interests who were also geographically representative of the communities in the watershed. Harvard University President, Nathan M. Pusey, headed the work of initial organization of the Committee. Past and present members, their communities and the watershed interests they represent are as follows:

<u>Name</u>	<u>Watershed Interest</u>	<u>Residence</u>
Mrs. Talbot Baker	LWV, Chas. R. Group	Millis
Chas. W. Bartlett	Broad Public Interest	Dedham
Thos. D. Cabot	Broad Public Interest	Weston
Ms. Roberta Chestnut	Fenway	Back Bay
F. S. Christian	Boston Ch. Commerce	Boston
Wm. H. Claflin	Broad Public Interest	Belmont
Henry J. Columbo	Mass. Wildlife Fed'n	Wilmington
M. J. Feldman	Broad Public Interest	Boston
E. M. Ferris	Newton City Planner	Newton
Ms. Karen Fisher	Fenway	Boston
Mrs. F. M. Forbes	LWV	Boston
John J. Gill	Town Planning Board	Needham
Mrs. H. S. Goodhue	LWV, Chas. R. Group	Wellesley
F. J. Gottlich	Electric Utilities	Boston
Mrs. R. Haddleton	LWV, Chas. R. Group	Dover
R. C. Hill	Middlesex Soil Conserva- tion District	Bellingham
W. W. Horvath	Academic	Cambridge
Bruce Lund	Mass. Audubon Society	Natick
H. McIntyre, Jr., MD	Up-River Regatta	Cambridge
James Miller	Newton City Planner	Auburndale
Alan Minoff	Sierra Club	Cambridge
Mrs. T. P. Murray	LWV, Chas. R. Group	Franklin
George A. Orrok	Electric Utilities	Cambridge
J. F. Plimpton	Mass. Forest & Park Assn.	Sherborn
Thos. Prentiss	Manufacturing in Flood Plains	Wenham
Henri Prunaret	Town Planning Board	Natick
Nathan M. Pusey	All major academic institutions	Cambridge

<u>Name</u>	<u>Watershed Interest</u>	<u>Residence</u>
L. Saltonstall	Broad Public Interest	Dover
Benj. J. Shattuck	Pres. Newton Conservators	Newton
Geo. C. Shattuck, MD	Nature Conservancy	Brookline
Robert T. Symonds	Supt. Milford Water Co.	Milford
Daniel G. Wheeler	Major Realtors-Developers	Dover
W. M. Whitehill	Historic Preservation	No. Andover
Kenneth H. Wood	Chas. R. Watershed Assn.	Norfolk
Robert Yasi	Legislative Interest	Boston
Governor's Legislative Council	The electoral districts of 60 House Members and 10 Mass. Senators are wholly or partly in the Charles River Watershed	

The Citizens Advisory Committee furnished assistance to the Corps by making recommendations in areas of thinking familiar to the members, suggesting the timing of the planning and in making the general public as active participants as possible. This group has made known the desires of watershed interests and has been a sounding board for study proposals throughout the five year study. The Committee held thirteen meetings in addition to, and separate from, the Coordinating Committee meetings.

Two months prior to the formal public meeting, twelve informational meetings, sponsored by the Citizens Advisory Committee were held in the following communities affected by the study considerations:

<u>Community</u>	<u>Date</u>
Norfolk-Wrentham	30 March 1971
Millis	31 March 1971
Franklin	5 April 1971
Sherborn	15 April 1971
Natick	16 April 1971
Dover	20 April 1971
Bellingham	21 April 1971
Dedham	22 April 1971
Holliston	27 April 1971
Medfield	28 April 1971
Medway	29 April 1971
Needham	12 May 1971

The purpose of these meetings was to acquaint local officials and townspeople with the findings and considerations of the Soil Conservation Service and the Corps of Engineers. Major objectives were to have citizen participation in the final proposals of the study, and to incorporate

their suggestions in the final plan. The local people did come out, both to be informed and to express themselves. More than 600 took advantage of this opportunity. At each of these informational meetings, a presentation was made indicating the opportunities of the watershed acting as a unit, with specific consideration in the local communities. The meetings were then opened to general discussion and questions from the floor. The results of the meetings were compiled and incorporated into the study recommendations.

4. COORDINATING COMMITTEE MEETINGS

First Coordinating Committee Meeting - 7 December 1966

A meeting was held on 7 December 1966 to establish the Charles River Basin Coordinating Committee. Discussion concerned first, the objectives of the Charles River Study and second, the formulation of the Plan of Survey for the watershed. The Plan, to be reviewed by participants, will include the desires of local interests as expressed at public hearings.

The number of members expected to participate in the Coordinating Committee was put at eight or more, including representatives of the Massachusetts Metropolitan District Commission and the Department of Natural Resources and the U. S. Departments of the Army; Agriculture; Interior; Health, Education and Welfare; Housing and Urban Development; and Commerce or Transportation.

A general feeling of cooperation was noted. Participants were informed of the general scheduling of meetings and expected distribution of published minutes of meetings.

An open discussion period heard comments on topics which would be major items considered at later meetings, such as the availability of land for acquisition in the middle and upper watershed; the existence of 45 sewer overflow outfalls in core cities of the watershed; the need for excluding salt water from the lower basin; the diversion of Mother Brook; and the predicted water supply shortage in the watershed, which may necessitate eventual change in the waste disposal method.

Second Coordinating Committee Meeting - 18 April 1967

The second meeting emphasized that the Charles River Basin is the outstanding natural resource of Boston and must be preserved by acquisition of land along its banks and clearing of pollution. A long term

program of acquisition to insure public access should start now before land values rise further. Ownership or control of a strip of land, a minimum of 150 feet deep all along the river basin was hoped for.

HUD programs with grants or loans are available to communities, it was learned. However, the shortage of program funds presents difficulties. Open space grants have been made in the Boston area. The Massachusetts Department of Natural Resources reported that \$1 million in funds was being requested for the coming year to meet requests by conservation commissions desiring open space acquisition.

The Commissioner of the Metropolitan District Commission stated that the Warren Avenue Dam has been studied for a long time. Its construction by the MDC is required by legislative statute, and \$12 million has been made available.

Final plans for the Boston inner belt showed that the construction would aggravate the Muddy River run-off problem.

Programs of sewerage improvement were examined. All Charles River sewage is now brought to a storage point near the Boston University Bridge. A storm detention system designed to handle five-year storms can store sewage before release into the main sewer system. The quality of water in the lower portion of the basin will be greatly improved due to reduction of sewage overflows brought about by the improved system.

Combined disposal of storm run-off and sewage is being considered as an alternative to separation of sewage for disposal. The combined plan, a system of tunnels feeding into a deep tunnel extending beyond Deer Island, would store inflow during storm periods and discharge out to sea, thus avoiding pollution of Boston Harbor.

Water quality and water supply were discussed. It will take six or seven years to achieve the desired water quality. Water available in the Upper Charles Watershed will be insufficient to meet local needs within fifty years.

The most important points brought up at the second meeting were:

a. The need for a long term program of land acquisition with requests for grants of Federal funds.

b. The need for construction of the Warren Avenue Dam, already provided for by State statute.

c. The existing improvement of the system sewage separation and disposal along the Charles River and a considered proposal for a combined storm and sewage water system.

d. The future shortage of water of the desired quality in the watershed.

Third Coordinating Committee Meeting - 26 September 1967

The third Coordinating Committee meeting produced a BRA recommendation that river parkland be given a National Historic Recreation Landmark designation. Land use planning was urged as a means of preserving the scenic land corridor along the Charles and Muddy Rivers. Too much parkland has been taken for road and bridge construction, and the environment is threatened by pollution and encroachment. Provisions of access and pathways and other recreational development for bicyclists, pedestrians and boaters are needed.

A need continues for regulation and low flow augmentation of the Charles River, it was pointed out. Work by the FWPCA progresses on a mathematical model to show effects of adverse factors such as sewage input or excess run-off on the Charles.

The hydrology presentation showed that flooding on Muddy River could be reduced by structural and channel improvements. Lastly, a report on SCS investigations of storage on the Upper Charles revealed a potential of 47 sites.

Fourth Coordinating Committee Meeting - 15 February 1968

The fourth meeting opened with a brief status report on the study and on the interim report for the lower basin. Need was stressed for the Warren Avenue Dam and for associated pumping facilities, so that basin water levels and Muddy River floods can be controlled.

"Health is more than the absence of disease", according to the speaker for the Department of Health, Education and Welfare; the peoples health in the larger sense is related to their use of water resources. The quality of the water restricts recreational uses of the

river. Handling and disposing of solid wastes is still a critical unresolved problem here. The Charles undoubtedly contributes to the pollution of Boston Harbor.

There has been some recent improvement in the water quality of the river, but FWPCA sampling shows that sources of pollution still remain.

Increasing high-rise construction is adding to the population densities of the Lower Basin, projected to increase by 50 percent by the year 2000. There will be a corresponding increase in flood damage potential and demand for recreational opportunities. Therefore, State and Federal interest in Charles River flood control, navigation, and pollution reduction will become more justified than ever.

"Open Space" was the topic of the talk by the Commissioner of the Department of Natural Resources. He urged support of the "Wetlands" bill then before the legislature and stressed the need to obtain matching funds for Federal grants for land acquisition.

Fifth Coordinating Committee Meeting - 12 September 1968

The fifth meeting focused on the Middle and Upper Watershed. Discussion of water supply in the upstream communities showed this as a growing problem. Low flow augmentation, dilution of sewage effluents and improvements for recreation and fish and wildlife are benefits that may be derived from tributary storage reservoirs. Of 47 potential sites studied by the Soil Conservation Service, 29 are adaptable to 3-5 foot depths; 18 to deeper water storage.

The preservation of marshland - a desire expressed at the public hearings - will also preserve natural valley storage. About 2 or 3 percent of the drainage area above the Silk Mill Dam can store up to 20 percent of the run-off from major storms. Report on the progress of a Federal Pollution Control Agency study of water quality showed that organic wastes discharged in the Charles at times have depleted the oxygen level below requirements for good fish habitat. Future waste load based on MAPC projection of population and computer analysis of low flow augmentation needs are planned. A Corps representative described a computer model which would supplement the engineer's judgment as to the best among alternative water quality measures.

A program of slides illustrating the environment from the headwaters to the South Natick Dam concluded the meeting.

Sixth Coordinating Committee Meeting - 5 March 1969

The sixth meeting amplified discussion of topics introduced at previous meetings.

Opportunities for open space acquisition in the Upper Charles were found physically limited while population growth and urban expansion go uninhibited according to a Department of Natural Resources urban planner. Extensive acquisition may favor the construction of multiple story housing rather than single homes.

The Corps hydrologist demonstrated by analysis of flood hydrographs that natural storage areas in the Charles River watershed prevent flooding in the volume experienced on comparable New England rivers. The most important area, in terms of its effect on flooding, is in the reach between the Medway and South Natick Dams where about 3,200 acres of swamp land storage reduces and retards flood peaks before they reach the Lower Charles. Future filling and build-up of these areas would result in a great increase in flood level downstream.

Retaining natural valley storage will also benefit recreational use of fish and wildlife; the more so because demand for recreation will increase as a result of population growth.

It was suggested that public agencies might create a common fund for land purchase, or might restrict use of land to prevent unwise use.

The Charles will receive major consideration in the Northeastern United States Water Supply (NEWS) Study by the Corps of Engineers. NEWS input to the Charles River Study will be limited to a regional scope, but the interplay between the two studies could complement the total effort to meet demands within the watershed. These demands will increase. Thirteen of the watershed communities not presently drawing on the MDC water supply will be unable to meet water supply needs from present sources by the mid 1970's.

A review of water quality and treatment by the Massachusetts Division of Water Pollution Control reported that all the waters of the State had been classified with the result that municipalities are eligible for State and Federal grants amounting to as much as 80 percent of the cost of construction of a municipal or multi-industry treatment plant. The Charles is classified as "B" or "C" for most of its length. Class "B" permits swimming and water supply use after treatment; "C" is adequate for boating and fish habitat and has fine aesthetic characteristics.

The FWPCA has established the mathematical model promised at an earlier meeting. This will indicate the river's dissolved oxygen response to variations in waste loadings and volumes of streamflow.

Estimates of future requirements, based on expected population growth, indicate that communities will need to aerate effluents and provide more treatment than secondary treatment. Studies will consider the relative merits of alternatives: transportation of wastes to the MDC system or a combination of treatment and storage.

Seventh Coordinating Committee Meeting - 12 June 1969

The seventh meeting was devoted to participation by representatives of groups (other than governmental) having an interest in the Charles River.

A representative of the Citizens Advisory Committee, also a member of the Watershed Association presented the existing conditions along the river by means of color slides and commentary. He appraised the many values of the river - those lost through misuse as well as those saved - and stressed the need to preserve land from build-up.

The Charles River Valley Group of the League of Women Voters expressed complete agreement with the Coordinating Committee's emphasis on preserving open space but believed the public had not always been fully informed of the reasons for the proposed works of improvement. The League urged release to the public of all information brought together since the inception of the study and the inclusion of citizens in the decision making part of the planning.

A lively discussion of the pros and cons of fishways at the various Charles River dams followed.

It was pointed out that the fate of the Charles River Valley depends on willingness to spend the money necessary to preserve its resources and environment.

Eighth Coordinating Committee Meeting - 20 November 1969

The eighth meeting began with review of Committee progress. The chairman cited the need to accommodate all points of view, even opposing views.

Studies of impoundment sites on the Charles River and real estate values in and around the areas of investigation were discussed. Of 47

tributary impoundment sites listed, 26 were found worthy of future studies.

The benefits to be derived from low flow augmentation were described as good by a speaker from the FWPCA. Use of a mathematical model to determine flow requirements aided the study of savings in treatment cost that would accrue from augmentation.

A planner from the Massachusetts Department of Natural Resources reported that some 2,300 acres are in public ownership within a corridor extending 1/2 mile from the banks on both sides of the river in the reach upstream of the Natick town line. He urged that towns request the river be designated a national scenic river.

Some improvement of the water quality in the Lower Charles River Basin as a result of the recent work of the Metropolitan District Commission was noted.

A summary of the progress of the Geological Survey in charting stream flows, including underground water concluded the meeting.

Ninth Coordinating Committee Meeting - 8 April 1971

The ninth meeting reviewed the study progress since 24 June 1965 and the assistance the Citizens Advisory Committee has given the Corps in formulating the plan. The plan, as proposed by the Corps, is primarily for preservation of 17 major wetlands for containing potential damaging flood waters and is referred to as an environmental protection action prospectus.

Favorable comments were made by both the Massachusetts Audubon Society and Sierra Club members.

Final input to the study report was discussed by member agencies and the extent to which they participate.

There was discussion as to the role of the Citizens Advisory Committee upon completion of the Coordinating Committee's report. It was noted that there will be an interim period of time, maybe two years, before actual implementation. It was suggested that the Citizens Advisory Committee remain active at least through authorization of the report.

The meeting concluded by stressing the need for public support at the public meeting, and at project justification meetings, and the need for letters to Congressional members.

5. PUBLICATIONS

During the course of the study numerous pamphlets, referred to as interim memos, were prepared to inform study participants of potential resources as they were being inventoried. These memos, after review and comment by participants, were made available to the general public, thereby generating additional interest and awareness in the study and the study progress. The following memos were distributed:

INTERIM MEMOS

HYDRAULICS AND HYDROLOGY

- #1 Watershed Areas
- #2 1967 Charles River Basin Sonic Soundings
- #3 Flood Plain Management and Flood Insurance

WATER RESOURCES

- #1 Stony Brook Sub-watershed

SOCIAL AND ECONOMIC DATA

- #1 Charles River Population and Urbanization
- #2 Higher Education

CHARLES RIVER ARCHEOLOGICAL SURVEY MEMO

RECREATION

- #1 Open Space and Recreation Aspects of the Lower Basin
- #2 Recreation Boating Downstream of Moody Street Dam and Other Navigational Data
- #3 Inventory of Recreation Resources Downstream of Moody Street
- #4 Supplemental Inventory of Recreation Areas in Boston, Brookline, Cambridge, Newton, Waltham and Watertown
- #5 Upper Charles River Canoe Ways Upstream of Moody Street Dam
- #6 Proposed Bikeway Systems for Lower Basin and Muddy River

U. S. DEPARTMENT OF AGRICULTURE

- #1 Water and Related Land Resources of the Upper Charles River Tributaries

6. PUBLIC MEETINGS

a. Starting early in the study, every attempt was made to determine the desires of the general public. Three formal public meetings were held in Waltham, Wellesley, and Franklin on January 17, 19, and 24, 1967, respectively. A digest of these meetings was incorporated in the Interim Report and therefore is not included in this report.

b. Toward the conclusion of the study, a public meeting was held in Medfield, on 13 May 1971, to inform the public of the study findings. The complete transcript of this meeting is on file in our Waltham Office, and this digest has been developed from the minutes.

FINAL PUBLIC MEETING - 13 MAY 1971

This digest has been developed from the minutes of the public meeting conducted by the Corps of Engineers, New England Division. The meeting was held in the Dale Street School auditorium in Medfield, Massachusetts at 8 P. M.

The meeting was chaired by Colonel Frank P. Bane who described the unique hydraulic characteristics of the Charles River by which the wetlands act as natural flood control reservoirs. However, we are now losing our wetlands because of urbanization, and serious flooding will occur in the future. Protecting these areas can be accomplished through flowage easements or acquisition in fee. The environmental protection action prospectus, as proposed by the Corps of Engineers, is primarily for the preservation of 17 major wetlands for containing damaging flood waters.

Mr. Arthur Brownell, Commissioner, Massachusetts Department of Natural Resources, presented the highlights of the State's recommendations for preservation of some 22,000 acres. Eleven thousand acres are within a one mile wide river corridor, the other 11,000 are outside the corridor. Mr. Brownell made the point that existing State legislation may permit the Department of Natural Resources to put forward the 20 percent non-Federal share of the proposed 80-20 cost sharing for 8,500 acres of land. He said this would be a practical way of assuring early accomplishment of the natural valley storage proposal. Individual municipalities should designate properties to be protected. Local communities may receive 50 percent Federal and 25 percent State aid in protecting property for open space through the self-help program. He noted that his office is the disbursing agent for this program and allocations of up to \$12 million have been brought forth since the fund first started in 1966. All that is required is a declaration of interest from the major wetland owners and from municipal officials as to the land they would

like protected and in what manner, either by easement or acquisition. Opportunities may exist for property tax and personal income tax offsets depending upon the nature of arrangement that is worked out. The State can act on a broader geographical scale but prefers to act through the municipality which either cannot, or prefer not to, act.

Mr. Walter Newman, Senior Staff Associate of the New England River Basins Commission (NERBC) stressed the needs for flood damage control, water quality, streamflow regulation, and preservation of natural values in the Charles River. The NERBC supports the Corps program for natural valley storages and considers it unique, innovative, and precedent-setting, a departure from the traditional, economic, and ecological principles. Further, Mr. Newman noted that the Charles River plan will provide an important input and pattern which will serve to significantly strengthen the management blueprint developed under the Southeast New England Study being conducted by their office.

The following elected officials sent representatives to the meeting as observers:

<u>Official</u>	<u>Represented by</u>
Senator Edward Kennedy	Mr. Albert C. Pierce
Congresswoman Margaret Heckler	Miss Carol Isber
Congresswoman Louise Day Hicks	Mr. Richard Luccio
Congressman Robert F. Drinan	Mrs. Jean Crosby

The first town official to speak was Mr. Henry J. Lewandowski, Selectman, Town of Millis. Mr. Lewandowski was concerned about equitable settlements for property owners for loss of their land and proper compensation by either the State or the Federal government. Millis has 23 percent of its lands designated as natural valley storage.

Mr. H. B. Willis, Jr., of the Weston Conservation Commission was concerned with water quality conditions of the Charles as it affects water supply with the point made that chloride pollution is coming from road salt entering into their system since the early 1960's when the major network of roads was put into the watershed. (See letters of comment.)

Mrs. Robert H. Smith, Wellesley Conservation Commission read a statement for their Chairman, Mr. Franklin Sanders, wherein the Corps recommendation of preserving the natural water storage areas was commended. Much progress has been made in solving the pollution problem but we are waiting the time when the quality becomes "B" classification and its full potential as a recreational and environmental asset is realized.

Mr. Stanley Olee, Waltham Health Department, pointed out the problems they are having at Purgatory Cove and wanted the MDC and the Department of Natural Resources to help resolve this problem.

Mr. Robert M. Morse of the Millis Conservation Commission feels many landowners would prefer conservation easements to Federal acquisition.

Mrs. Harold Burstein of the Waltham Conservation Commission wants natural valley storage Area A in the Beaver Brook watershed to be reinstated in the plan.

Mr. George H. Wallace, Chairman of the Natick Conservation Commission had very strong reservations regarding low flow augmentation sites unless such sites were used for multiple-purpose recreation and properly managed.

Mrs. H. Shippen Goodhue of the Charles River Valley Group League of Women Voters spoke on behalf of 18 leagues that are in the Charles watershed. She complimented the Corps and other coordinating committee agencies on the information and coordination that was generated by the study. She requested that Area A be included in the plan and asked that the impoundments of the Soil Conservation Service not be forced upon the towns. Prior to the construction of impoundments, several things should be examined, such as pollution upstream of the impoundment, the fact that the impoundment should not add pollution, and finally, the importance of recreational use. Her most important point was who should bear the responsibility for the daily maintenance and policing of such areas either from a Federal, State or local area of influence. She hoped further that the Charles would be classified as a "B" river in years to come. Her final statement concerned the publishing of a booklet which would contain the essential facts and proposals. This booklet would be geared to the citizens who have interest in preserving the Charles and in taking action. In addition, she asked that the present Coordinating Committee of agencies continue to meet regularly during the implementation phase of the study, and that the Charles River Citizens Council be formed from the various active members of the Citizens Advisory Committee to the Corps study.

The next speaker, Mr. Charles Eliot of Cambridge, gave a statement of applause and encouragement for the Corps proposal, speaking of it as a breakthrough for sound planning by the Corps, and of national significance. The acquisition and preservation in perpetuity he felt was one of the better ways to halt the spreading serious flood problem.

Mr. Bruce L. Lund of the Massachusetts Audubon Society, representing over 20,000 citizens concerned with the environment of Massachusetts went on record as supporting the Army Corps' plan for protection of the existing wetlands. He questioned some of the purposes of the Soil Conservation Service's proposed impoundments. Pollution should not be diluted, but rather cured at its place of origin. He felt that we ought to use the Wetlands Act wherever possible in lieu of the Federal acquisition because the people would feel more at ease with the State plan than with a Federal plan.

Mr. P. L. Reid, Jr., of the Upland Game Inc., wanted to know whether there were appropriate laws to prohibit people from filling the wetlands. Mr. Brownell responded that there are two types of wetlands protection in Massachusetts at the moment. These are the Hatch Act, which he said isn't working, and the Inland Wetlands Program which has just got under way. The Inland Wetlands Program, he felt, can restrict land before development takes place, and he believed this to be a working program. Mr. Brownell discussed the Conservation Restriction Act of 1969 which enables the towns to purchase wetlands for preservation. This latter law is a total restriction program, not necessarily a preservation program because use is permitted but destruction of the character of the wetlands is not permitted.

Mr. Lester W. Leonard of the Greater Boston Sportsman Association felt the plan was a bold move and complimented the Corps of Engineers.

Mr. Alan R. Minoff of the Sierra Club, boasting over 120,000 members, presented his statement on behalf of the New England Chapter which he says numbers more than 4,000. He strongly supports the Corps proposals. He said further that the tax loss to the town of Millis, to the best of his estimate, was about \$30,000 a year, and a small loss in comparison to the damage to be prevented by the plan. He felt they should be compensated for it but that it should not stand in the way of the program moving forward. He favored the outright purchase of the land rather than the procurement of easements, restricting various filling operations which he felt over a period of time would be nibbled away. In addition, he felt Federal acquisition would assure public access and thereby help meet recreational needs. He opposed the pools of the Soil Conservation Service and felt they would be very short lived in their usefulness, noting that existing impoundments in the Charles have been reported as significant sources of pollution. In addition, he felt that three of the proposed Soil Conservation Service areas are being considered as low flow augmentation pools when there isn't any flow to give away.

Mrs. Mary H. Fyffe of Wellesley Conservation Council, Inc., asked that the final report of the Corps, which she supports, feature large-scale, easy-to-read maps showing water levels of previous floods in areas inundated as compared with the extent of flooding which would occur during future floods if the wetlands are filled.

Dr. Joseph S. Larson, Professor, University of Massachusetts, Amherst, considers the Corps proposal as forward looking and precedent-setting. He pointed out that in certain communities near Boston, they are estimating that since 1951 there has been a range of 14 to 50 percent loss of the wetlands.

Mr. Anton A. Pruckner of Newton, Massachusetts hoped that the Corps' report would be very explicit on fair market value so the people would understand exactly what they would get and how they would get it.

Mr. H. M. Temple of Millis was very concerned about confusion of recreational use with conservation use. He feels that recreational activities should be limited in the tributary areas if the ecology there is to be preserved.

Mrs. Anne B. Perry, League of Women Voters, Sherborn indorses the plan for preservation of the natural valley storage areas but questioned the development of conservation pools.

Mr. Stanley McDonald, Jr., Sherborn felt that if the average person was aware of the significances of the plan he would heartily indorse it.

Mr. R. L. Frothingham, Dedham, strongly indorsed the stand of the Corps of Engineers.

Mr. Vincent N. Merrill, President of the Charles River Watershed Association thanked the Corps of Engineers and the other Coordinating Committee agencies for information and material furnished the Association. He believes Federal funds should be available to clean up rivers. The Association commended the Corps on their plan but was disappointed to see Area A along Beaver Brook dropped.

Mr. Lawrence G. Copley of Newton, President of the Cambridge Boat Club, supports the preservation of the quality of the environment. He said that his rowers use a "See and Avoid Principle" but noted that he has to compete with power boats in the river and was not too happy about this. He felt power boating should be restricted to the larger

water areas. He was horrified at the dumping that takes place along the banks of the river, causing floating debris.

Mr. Robert T. Symonds of the Milford Water Company, submitted a letter in support of enlarging Echo Lake which is a water supply source for Hopkinton and Milford, together with limited recreational use.

Mr. Thomas D. Clifford of Holliston Industrial Commission was concerned that economic objectives become consistent with environmental objectives.

Mr. William Kirschner, Student, Sudbury was in favor of the Corps' unprecedented work.

Mr. G. Graci of Millis had the following points, namely, how do we carry out flood plain zoning? Should we acquire the land or have easements? Why should towns like Millis give up land for downstream communities that continue to encroach the flood plain? He feels that the communities being asked to give up the land should be reimbursed by the towns that are benefitting from it. Secondly, he favors the route of easements versus acquisition, leaving it to property owners to police their own land.

Senator James DeNormandie spoke in favor of outright acquisition of as much of the land as was possible to acquire. He spoke of his experience with the Sudbury-Concord wildlife area, and it was his view that it is better for the Federal government to do it than the State. Further, it was proven that the Federal government is not as big a threat as some of the property owners thought it would be. They have been extremely fair and sensitive to the problems of the individuals who might own the property and that the prices given to them were fair. Regarding recreation, he cautioned about talking in terms of absolutes. He felt there are many proper uses consistent with conservation and ecological interests that have to be balanced.

Selectman George DeCristoforo of Holliston wanted it made clear as to the permanency of control if the land were taken by the Federal government or some other legislative act. Would then somebody in the State turn around and change it. The answer is definitely not, only another act of Congress could change it, assuming Congress so decreed that it be bought for this purpose. As an additive to this, Mr. DeNormandie re-emphasized the position that once the Federal government takes something not even the States can do anything about it, and for this reason he favors Federal acquisition.

There was considerable discussion raised by a property owner on behalf of his aged mother who has for several years been tending acres of land along the portion that is to be earmarked as the State's corridor. It was his view that the State should permit the taking of his land under an easement provision. Mr. Evan Hawes of the Massachusetts Department of Natural Resources claimed that this could probably be worked out. Toward the close of the meeting there were other questions raised as to the possibility of the Federal acquisition of land which might then be leased back to property owners on a long term basis. This type of procedure has been used elsewhere in the Corps and could be worked out if so desired. The last series of questions will be answered during the advanced engineering and design stage.

WATER RESOURCES INVESTIGATION
CHARLES RIVER STUDY

APPENDIX B
ECONOMICS

PREPARED BY
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASSACHUSETTS

DECEMBER 1971

APPENDIX B

ECONOMICS

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ECONOMICS

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APPENDIX B

ECONOMICS

1. INTRODUCTION

This Appendix examines the state of the Charles River Economic Area economy today, discusses the historical forces that have been influential in shaping its present-day character, and indicates what it is likely to be in the next 50 years. See Figure 1. Both economic and demographic information useful to water resources planning for the Area is provided. This information includes historical and projected estimates of population, labor force, employment by industry group, income and related measures. The historical years shown in this appendix are 1900, 1910, 1920, 1930, 1940, 1950, 1959, 1960, 1962, and 1965; projections are presented for each decadal year between 1970 and 2020. The areas for which projections and historical data are presented include the nation, New England, the general economic area in which the watershed is located, and sub-regions defined by town lines.

2. OBERS PROJECTIONS

In carrying out this task, data prepared by the Office of Business Economics (OBE), Department of Commerce, and the Economic Research Service (ERS), Department of Agriculture were examined to determine their usefulness in providing meaningful benchmark projections. These projections, referred to as "OBERS Projections", are conditional forecasts of the future. They are based on extensions of past relationships believed to have future relevance for the measures being projected. Underlying these extensions of past relationships are the assumptions that make the projections conditional forecasts. Thus, the projections are forecasts of what might occur if the particular assumptions were to materialize.

Certain assumptions regarding the structure and behavior of the economy are applicable to projections generally. Examples of these are:

- (1) The Federal government will implement the policies needed to maintain relatively full employment;

(2) Government and private policies will be successful in avoiding prolonged levels of inflation; and

(3) The economy will be free of the distorting effects of a major military conflict during the 50-year projection interval.

For water resources planning purposes, the assumptions underlying the OBERS Projection method yield what is essentially a "base line" projection. ¹That is, no explicit account is taken of the water resource endowments of the Area. The quantity and quality of available water will not necessarily be a factor in limiting future economic and population growth. It is assumed that water will play the same role in stimulating or depressing economic growth in the region in the future as it has in the past.

3. METHODOLOGY

The analytical approach followed in this appendix is to compare the prospective trends for the nation, and in some cases the New England region, to the Charles River Economic Area. Such an approach requires a more detailed understanding of the characteristics of the Area which was obtained from both secondary data sources and consultation with locally knowledgeable individuals.

The general procedure followed in making the OBERS Projections was first to project national totals of each of the relevant economic measures and then to disaggregate these national totals to regional levels. Implicit in this procedure is the fact that national forces clearly dominate economic development throughout the nation. The national economy approximates a closed economy whereas the regional economies, within the United States, are open. ²Goods and people move freely between regions. This assumption involving national forces is important for viewing the future economic growth of the Charles River Economic Area, an area which accounts for an impressive share of the nation's economic activity and whose industries market their products beyond the regional boundaries.

¹Part II, Appendix B, Economic Base, prepared by the Office of Business Economics, Regional Economics Division, for the North Atlantic Regional Water Resources Study, pp. 39-40.

²The foreign trade sector of the national economy is relatively small.

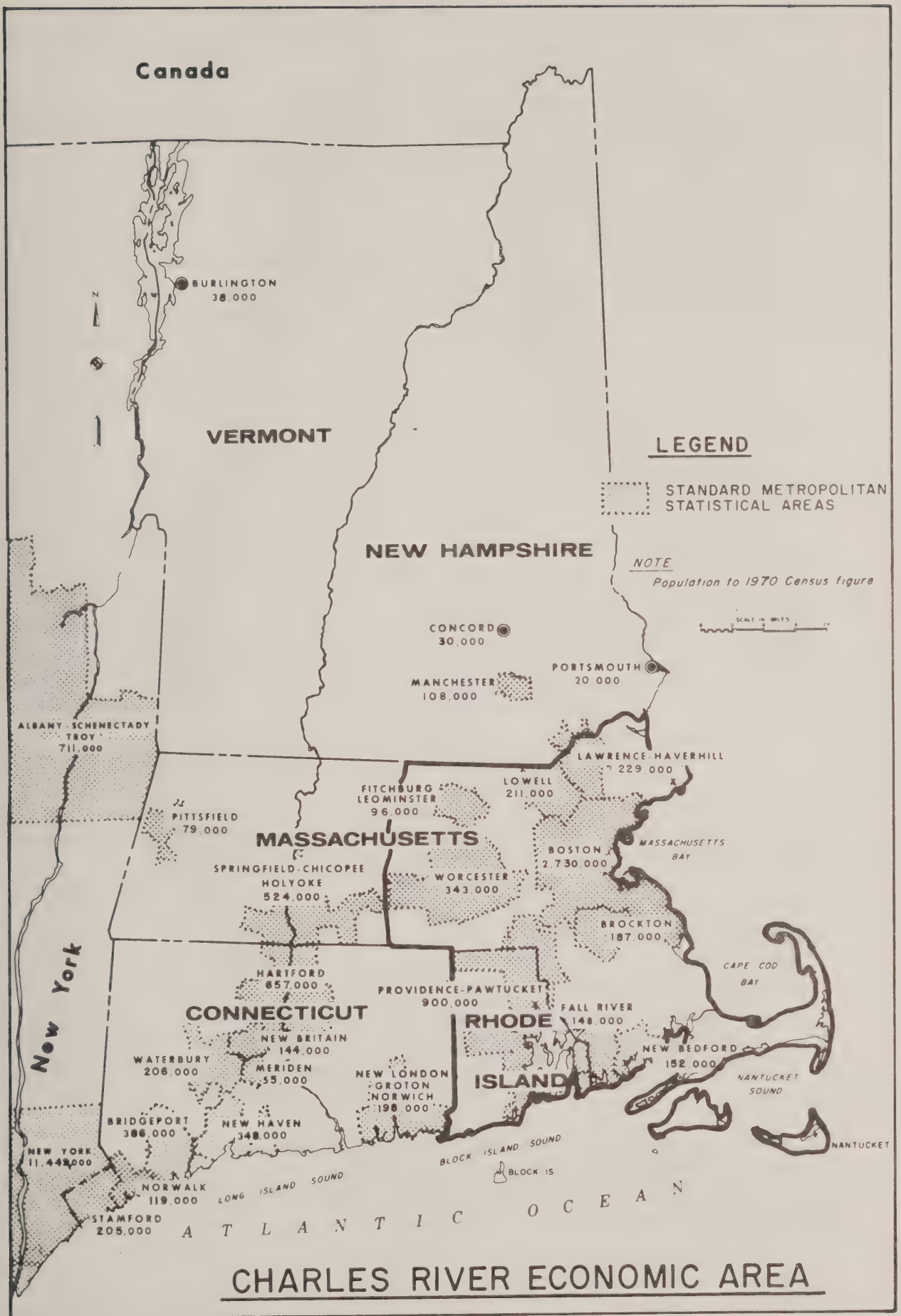


FIGURE I

National projections of the overall economy were made in terms of benchmark aggregates such as gross national product, population, employment, and personal income. From these summary measures were derived national totals of the economic series to be projected for local areas. Because of a lack of gross area product data that extends over a substantial time period, a firm national-regional relationship of this measure could not be established. It is for this reason that population, employment, personal income and earnings were chosen as measures to be disaggregated to economic subareas for estimating the overall expansion of water resource requirements.

4. MAJOR FINDINGS

In general, the examined historical data and projections derived therefrom indicate that the economy of the Charles River Economic Area will continue to expand and prosper in the period 1970-2020. In so doing, the region will continue to export valuable services and manufactured goods beyond its boundaries. Changes within and among the Area's various economic sectors are, of course, inevitable and will play a dominant role in determining its growth path. Human dynamics, especially population, urbanization, employment, personal income, and the nature and composition of the industrial and business mix of the economy will be of special relevance to the complex water resource problems and needs of the basin.

The major findings of this study are as follows:

(1) Population in the Charles River Economic Area is expected to increase by a factor of 1.7 by the year 2020, although a decline is anticipated in relation to the total population of the United States from 2.8 percent to 2.4 percent of the national figure.

(2) Total personal income in the Area is expected to rise by a factor of 6.5 by the end of the projection period. Since the Area's population will be 1.7 times greater, per capita personal income will rise almost fourfold. Although per capita income in the Area will remain higher than that of the nation as a whole, it is projected to converge from roughly 9 percent higher than the national average in 1970 to 4 percent higher in the year 2020.

(3) The manufacturing sector is declining and is projected to further decline relative to the nonmanufacturing jobs with employment in the services expected to increase 160 percent. Expanding population and rising personal income indicate further advances for urban services

such as finance, insurance, real estate, and medical and health. Thus, the projections of manufacturing and nonmanufacturing employment show the structural shift which the Area economy is expected to experience.

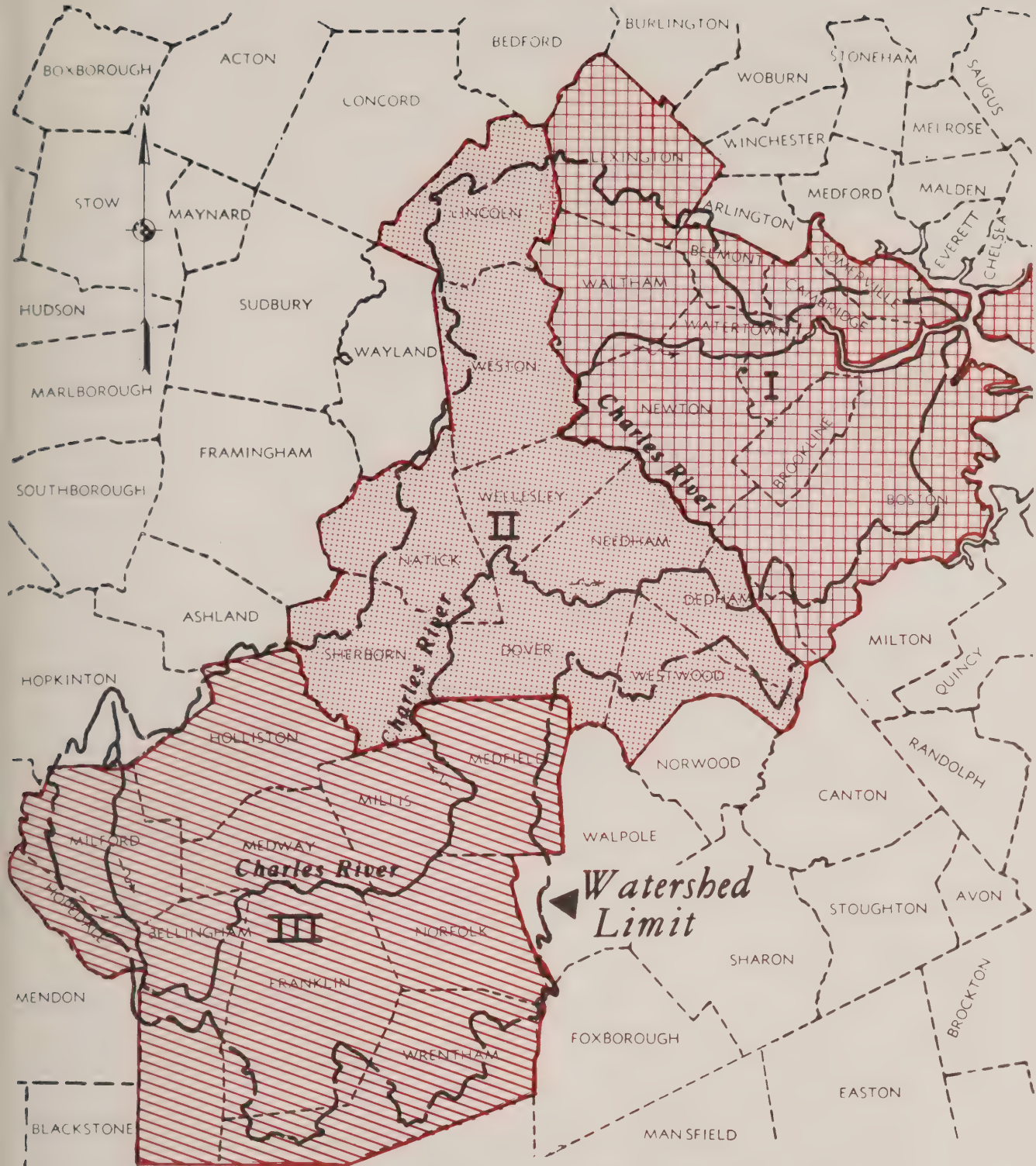
(4) Although population in the Lower Charles subregion has been declining, it is expected to stabilize by 1980. The Middle and Upper subregions will continue to gain in population at the expense of the Lower Charles as the trend of flight from the urban centers to the suburbs continues. The most immediate effects will be felt in those communities within commuting distance of the Boston Metropolitan area. In addition, the recently constructed Interstate Route 495 expressway is also expected to attract new industry and population to the Upper Charles subregion.

NATIONAL AND AREA TRENDS IN ECONOMIC AND DEMOGRAPHIC ACTIVITY

5. INTRODUCTION

Paragraphs 6 and 7 describe past changes in the economic growth of the Charles River Economic Area as compared to United States' growth and discusses the historical forces that have been influential in shaping its present-day character. This sets the stage for the later discussion which analyzes the future growth of the Charles River Economic Area and compares it to projected national economic growth. In addition, this serves as a point of departure for the analysis of future economic growth of the Charles subregions which are discussed in the paragraphs 13 to 15. The purpose is to provide the necessary economic and demographic information essential for assessing the future demand for water and related land resource goods and services in the Charles River Economic Area and Subregions. See Figure 2.

The Economic Area chosen for study in this chapter is Boston Water Resources Planning Area 0106 of the North Atlantic Regional Water Resources Study prepared by the Office of Business Economics, Regional Economics Division, Department of Commerce. This area is derived from one of 167 national economic areas delineated by the Office of Business Economics, each of which forms a complete and integrated unit characterized by comparative stability in interindustry relationships. ³Projected values for these economic areas were



CHARLES RIVER WATERSHED

0 5
SCALE IN MILES

ECONOMIC SUB-REGIONS



LOWER CHARLES



MID-CHARLES



UPPER CHARLES

FIGURE 2

disaggregated and the component parts reassembled into Water Resources Planning Areas which had been designated by the various water resource agencies.

As defined above, the Boston Water Resources Planning Area, hereafter referred to as the Charles River Economic Area, is delineated on the basis of economic rather than hydrologic considerations. This delineation is based on central-place theory, or the nodal-functional area concept, which recognizes that to each urban center are attached surrounding county units in which economic activity is focused directly or indirectly on the nodal center. Thus, the economic area combines the place of residence and place of work of employees as nearly as possible so that there is a minimum of commuting from home to work across economic area boundaries.

In this Appendix, economic change is measured by a set of interrelated variables, namely population, labor force employment, personal income, earnings and net output. These indicators express in economic terms the need for water resource development in an area. Especially important are the numbers of people projected to live in an area and any expected changes in industrial activity. Industrial output or activity at the national level is measured by gross national product. At the regional level, however, there are no official corresponding measures to the annual national output of goods and services. Therefore, employment data which is available in detail at the regional level is used to indicate changes in industrial activity and total personal income provides an overall measure of regional economic growth.

6. THE AREA SETTING

The Charles River Economic Area is geographically and economically a part of the largest employment and population cluster in New England. This cluster is the northern terminus of "megalopolis", the Atlantic coastal strip between Washington and Boston in which live about 44 million people, nearly one-fifth of the United States population.

³ Part I, Appendix B, Economic Base, prepared by the Office of Business Economics, Regional Economics Division, for the North Atlantic Region Water Resources Study, p. 23.

Located in the Charles River Economic Area are the principal governmental, commercial, industrial, educational, medical, financial, insurance, and cultural institutions of New England. In it are nine SMSA's with a combined 1970 population of almost 5 million people. The cultural assets, universities, historic structures, and museum and library treasures found in the area are of national and international importance.

The share of the total labor force employed in the manufacturing industries is higher than the national average. This manufacturing activity is quite diversified with some specialization occurring in the individual cities and towns. The area as a whole shows a degree of specialization in miscellaneous manufacturing, electrical machinery, textiles, professional services, trade and construction. The rapidly expanding electrical machinery industry has surpassed the textile industry in numbers as the leading employer in the manufacturing sector. Other manufacturing industries which are major employers include non-electrical machinery, apparel, food and kindred products, fabricated metals and printing and publishing.

At the head of the watershed lies the City of Boston, the Massachusetts State capitol and the most populous city in New England. It is the center of the eighth largest SMSA in the country and along with its surrounding communities of Brookline, Cambridge, Newton, Dedham, Quincy, Milton, and Watertown is the economic hub of the Area.

The Boston area has experienced a remarkable growth in technologically-oriented industries which have located here in response to, or as spinoffs of, the concentration of advanced education and research facilities. Among the colleges located in the area are Boston College, Boston University, Harvard, MIT, Northeastern University, Radcliffe, Tufts, Wellesley and several Massachusetts State colleges.

7. PAST TRENDS IN ECONOMIC GROWTH

a. General.

The prospect for future economic growth in any region is dependent on past trends and current conditions. First, past changes in the Economic Area's population growth are described. As mentioned earlier, the need for water resource development in an area is primarily related to the number of people in an area.

This then is followed by sections dealing with personal income, industrial sources of regional earnings, and changes in employment labor force.

b. Trends in Population.

Population in the Charles River Economic Area increased by 23.1 percent between 1929 and 1962, rising from a level of roughly four and one-third million to five and one-third million (see Table B-1a). The average annual rate of growth of 0.6 percent, however, was below the average rate of 1.3 percent for the nation during the same period, reflecting the region's loss of population through net outmigration (see Table B-1c). In the more recent period between 1950 and 1962 the area's average annual rate of population growth remained roughly at one-half the national rate. During the same time periods, the local growth rate was also below the New England rate.

These lagging rates of population growth are also reflected in the Area's decreasing percentage shares of New England and national populations. From a high of 3.6 percent of total United States population in 1929, the regional share had declined to 2.9 percent by 1962 (see Table B-1b). Likewise, its New England share has also declined over the same period. See Figure 3.

c. Past Trends in Personal Income.

Reflecting population trends, personal income growth in the Charles River Economic Area has also been slower than its national counterpart. Expressed in 1958 constant dollars, personal income in the nation increased from about \$155 billion in 1929 to about \$420 billion in 1962 (see Table B-2a). This represents an increase of 171 percent, or an average annual growth rate of 3 percent (see Table B-2c). Personal income in the Economic Area, however, expanded at an average annual rate of 1.9 percent during the same period, or by 87 percent in total.

From 1929 to 1962, the share of the nation's personal income received in the Area declined from 4.7 percent to 3.2 percent (see Table B-2b). The major part of this decline, 1.2 percent, occurred in the period 1929 to 1950. In the period 1950 to 1962, however, the Area's average annual rate of growth of personal income had more closely approached the national average which resulted in only an 0.3 percent decline in its percentage share of personal income (see Table B-2c).

d. Per Capita Personal Income.

The critical interplay between population growth and growth in total income is reflected in the per capita levels of income which have always been higher in the Charles River Economic Area than in the nation (see Table B-2a). These higher levels have been attributed to higher rates of labor force participation (see Table B-4a), substantial property income, and a larger-than-national share of employment in manufacturing (see Table B-4b). The regional trend since 1940, however, has been to converge toward the national level (see Table B-2a).

e. Industrial Sources of Regional Earnings.

Earnings of persons engaged in production, a major component of personal income, are made up of the sum of wages and salaries, proprietors' income and other labor income. ⁴As such, they are of key importance to the analysis of total personal income trends and to the probable course of future economic developments.

Table B-3b shows the percentage of earnings among the broad industrial sectors. Several conclusions may be drawn from this Table:

(1) Agriculture and mining play a less important role in the economy of the Area than they do in that of the nation. The share of agricultural labor earnings in the Area's total earnings have been roughly one-fifth or less of their national counterpart in past years. Earnings in mining in the region expressed as a percent of total earnings received by residents have also been well below the national shares.

(2) In contrast to the earnings generated by the resource industries in the Area economy, the share of total earnings paid to persons in the service industries has increased markedly since 1950. From 1929 to 1962, constant dollar earnings paid out by the service industries in the region increased by 124 percent (from roughly \$778 million to \$1.74 billion). Although this growth in area earnings was less than that for services nationwide (197 percent), the service industries were still more important regionally with a higher percentage share of total earnings than services in the nation.

⁴ The nonearnings portion of personal income consists of property income, transfer payments, and personal contributions for social insurance, the latter a deduction from personal income.

The reason for the service industries consistently higher shares of total earnings in the Economic Area is its economically mature character. The region, along with the rest of southern New England, appears to have been carried beyond the national stage of development, has already completed the process of transition from an extractive to a processing economy, and is now in the process of transition to a service-oriented economy.

(3) Reflecting this trend, earnings generated by manufacturing - the major source of earnings in the economy of the region - have been a declining share of total earnings since 1950. Expressed in 1958 constant dollars, manufacturing earnings totaled about \$4 billion in 1962, accounting for 34.6 percent of the area's total earnings. In 1950, however, manufacturing earnings totaled roughly \$3 billion, but accounted for almost 38 percent of the area's total earnings. Thus, while the area economy remains more dependent on manufacturing than does the economy of the nation, this sector has been declining as a regional source of earnings.

f. Trends in Industry Employment.

Past trends in industry employment have been similar to changes in the level and industrial composition of earnings discussed in the preceding section. Over the past 40 years, overall employment has grown slower in the Charles River Economic Area than in the nation (see Table B-4a). In the period 1929 to 1962, the average annual rate of growth of the Area's labor force has been, 0.9 percent while the national average annual rate has been almost 1.2 percent.

As previously noted, the resource industries, agriculture and mining, have been relatively less important in the Area's economy than in the national economy. Based on the employment mix (see Table B-4b), however, manufacturing, finance, insurance, real estate, services, and civilian government have been relatively equal or more important regionally. Contract construction has held a slightly smaller share of regional employment than its national counterpart since 1950 and trade has recently declined in regional importance in the last decade.

8. FUTURE PROJECTED ECONOMIC GROWTH

a. General.

Having reviewed past trends in the Charles River Economic Area, the prospect for future economic growth can be assessed.

b. Population.

Population in the Economic Area is projected to increase by roughly 4.1 million between 1970 and 2020 (see Table B-1). This represents a growth of 70.5 percent, or an average annual rate of 1.03 percent which is well above the rate for the period 1929 through 1962.

This increase in population is based on the estimate of labor force needs to meet the requirements of an expanding economy which the local regional labor force cannot accommodate. The proper starting point for understanding the prospects for future growth in a region is the realization that a community is a place for earning a living. In essence, population settles or expands in a region primarily because of employment opportunities. Hence, a migration into the area is projected based on the assumption that labor shortages will be avoided and economic activity will not be curtailed.

While regional population is projected to increase quite markedly in absolute numbers, growth rates will be higher for both New England and the nation as a result of newer and faster growing areas. Because the Charles River Economic Area got a jump on other areas of the nation by the mere fact that it was here first, it has already peaked as far as expansion goes. Thus, it is expected to experience a relative decrease in its regional percentage shares of New England and national populations as other areas of the nation continue to catch up and close the gap in the expansion process.

c. Total Personal Income.

In line with past trends, personal income growth in the Economic Area is projected to be surpassed by that in the nation (see Table B-2c). Expressed in constant 1958 dollars, it is expected to rise by a factor of roughly 6.5 in the period 1970 to 2020. As in the same case with population, however, the proportion of the nation's

personal income received by the Area's residents is projected to decrease. By the year 2020, the region's share is expected to be 2.5 percent as opposed to the 1970 level of 3.1 percent.

d. Per Capita Personal Income.

With population projected to increase by a factor of 1.7 and total personal income by a factor of 6.5, per capita income will rise almost fourfold over the projection period. Although per capita income is projected to remain higher than that of the nation as a whole, the regional trend to converge toward the national level is also to continue. From a projected high of 1.09 in 1970, the index for Area per capita income relative to the United States average is expected to decrease to 1.04 by the year 2020. This projection is based on a gradual maturing of more recently developed sections of the country and the concurrent lowering of regional differences in economic opportunities.

e. Industrial Sources of Regional Earnings.

Projections of earnings derived from agriculture in the Charles River Economic Area imply a further decrease in this sector's relative share of total earnings, so that by the year 2020, it will drop to 0.4 percent. This continuation of the historical trend of agriculture is not unique to the region, but similar to that projected for the entire nation. In addition, the historical trend for the mining industry in both the Economic Area and the nation is also projected to continue over the next five decades, with mining in the region becoming almost of negligible importance.

Along with the resource industries, the projections for contract construction in the region also show a decline in this industry's relative share of total earnings, again due to the Area's maturity. Although there have been relatively rapid gains in the average construction worker's compensation, construction activity will expand at a relatively slower rate than other industry sectors in the already highly urbanized Economic Area. The same rationale might be used in explaining similar relative earnings declines in such industries as transportation, communications, and public utilities-industries whose growth rate depend heavily on the state of development of a particular area. The relative share of total earnings for these industries in the Area is expected to fall to 4.2 percent from a high of 5.9 percent during the projection period.

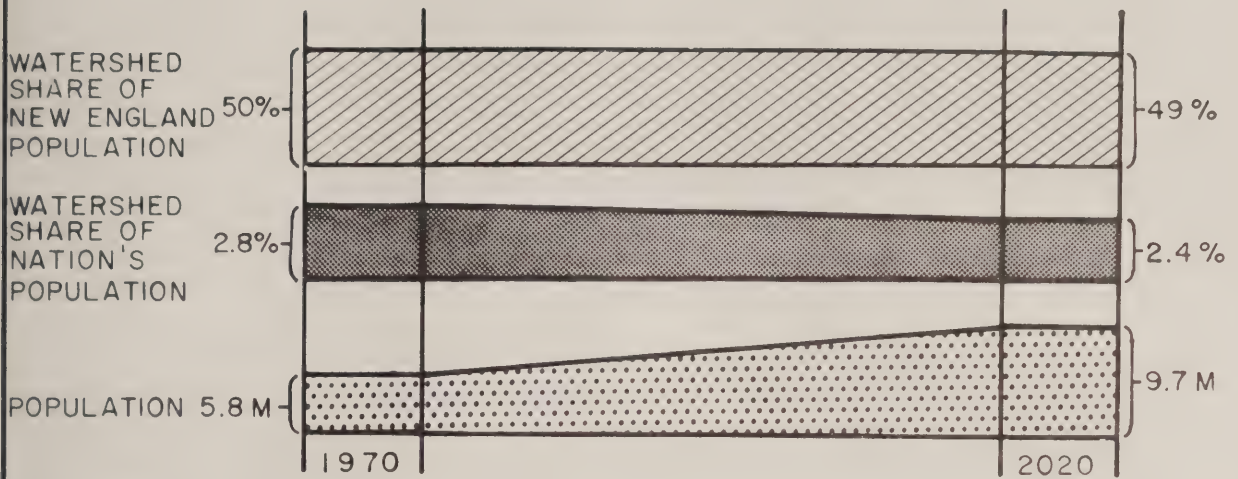
As for manufacturing, no significant departures from the historical trends are anticipated over the next five decades. The projections indicate a continued decrease in the relative earnings generated by this sector from roughly 34 percent of total regional earnings in 1970 to 26 percent by the end of the study interval.

In contrast to the projected slow growth of earnings generated by the industry sectors described above, compensation paid out to persons by civilian government (Federal, state and local) and the service industries is projected to increase rapidly both absolutely and as shares of total earnings in the region. The biggest jump in the regional relative earnings shares will occur in the service industries where by 2020 earnings paid in this sector will have increased to approximately one-quarter of total earnings in the Economic Area as opposed to 15.6 percent in 1970. The relative share of total earnings paid out by regional government will increase less dramatically from 14 percent to almost 18 percent during the same time period. Despite these favorable regional prospects, the two sectors will not become more important regionally than their national counterparts as similar trends are expected on a nationwide basis.

f. Industry Employment.

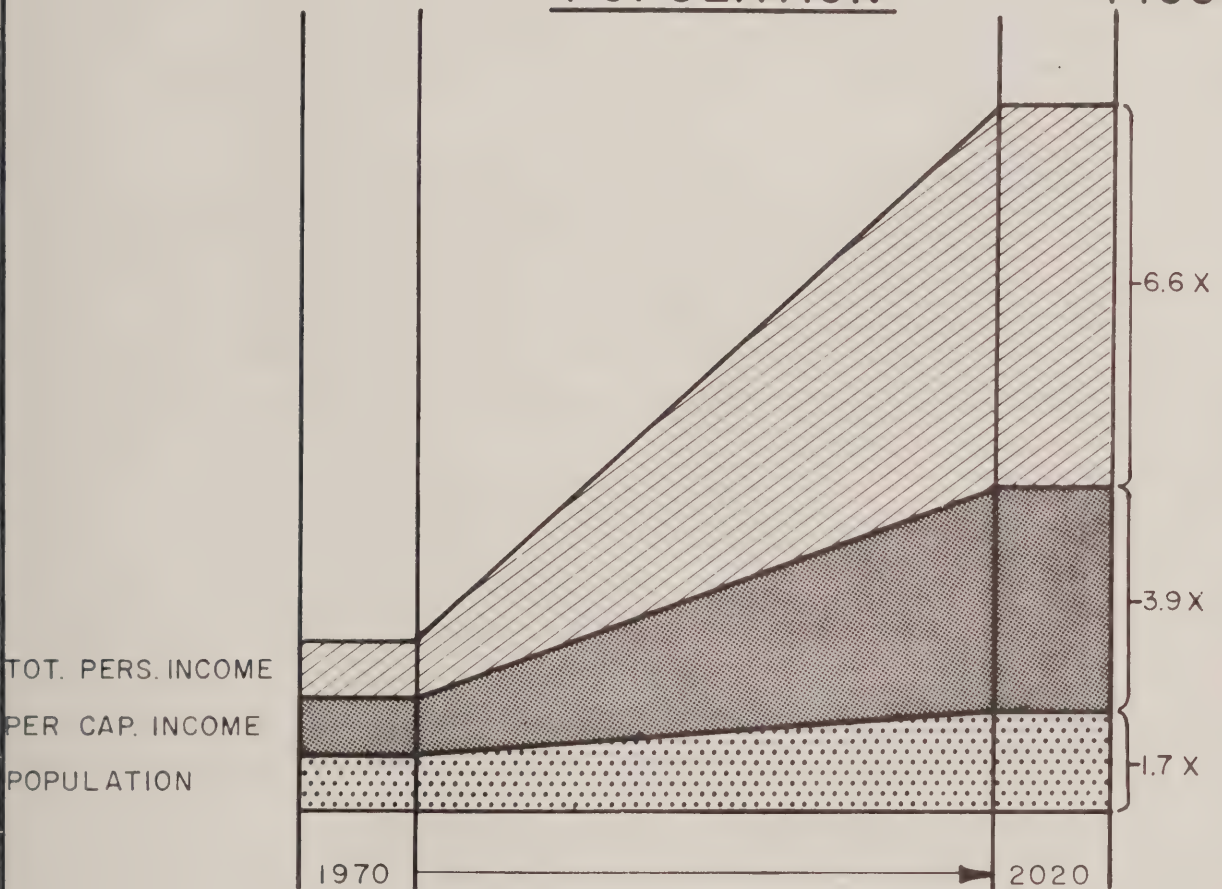
The changing characteristics of the Area's economy indicated by the changing composition of earnings disbursements described above is further documented by manufacturing and nonmanufacturing employment projections. While the Area economy will still remain more dependent on manufacturing than the national economy, this sector is projected to decline relative to the nonmanufacturing sector in importance as a source of employment in the Area (see Table B-4b.)

Employment in the Area's manufacturing industries is expected to drop from 33 percent of total employment in 1970 to roughly 23 percent by the year 2020. In the same time period, employment in the region's service industries is projected to increase its share of total employment from 25 percent to 38 percent. Thus, by the year 2020, there will be far more employees in nonmanufacturing positions, although total employment in manufacturing is expected to increase in absolute numbers by 24 percent.



POPULATION

FIGURE



PERSONAL INCOME

CHARLES RIVER SUB - REGIONS

Manufacturing or traditional industrial activity, however, is still projected to be of greater importance to the regional economy than it is to the national economy and appears to be in a potentially strong position for the future. As indicated in Table B-5, economic production per employee is expected to dramatically increase over the projection interval. This will in great part be a result of the changing mix of manufacturing industries from the labor-intensive to the capital-intensive. High productivity gains will be in the application of the region's highly skilled labor force and technological inputs from the engineering and scientific communities to a small volume of raw materials to produce highly valued finished products for export. See Figure 4.

With the pronounced orientation toward the nonmanufacturing sector, new concentrations of workers and occupational changes will occur. Finance, insurance, real estate, government, and business and private services stand out as the more important growth industries. As a growing population with higher per capita income spends a larger share of its income on non-commodity items, recreational activity, medical and health services, and business and educational services, employment in the services will grow faster than in any other industry group.

In essence, the projections of manufacturing and nonmanufacturing employment for the Charles River Economic Area show the structural shift which the economy is expected to experience. The Area is expected to further move away from an economy which is based on manufacturing toward an economy which is based on services while employment growth in the service sector will result from expanding population, increased general employment, and rising personal income.

SUBREGION PROFILES

9. INTRODUCTION

The following paragraphs describe the economic and demographic characteristics of the three subregions defined by town boundaries which comprise the Charles River Watershed (see Figure 2). The

purpose of dividing the watershed into subregions is to provide more meaningful entities for planning than are represented at the economic area level. For example, the Lower Subregion contrasts sharply with the Upper Subregion with respect to both current characteristics and development potential.

In essence, each subregion is different from the others, confronted by its own problems, and having differing capabilities which influence its prospects for future growth. These differences relate primarily to the watershed resources and production facilities in the region, the structure of its economic activity, and the characteristics of its population, work force, and industrial sectors.

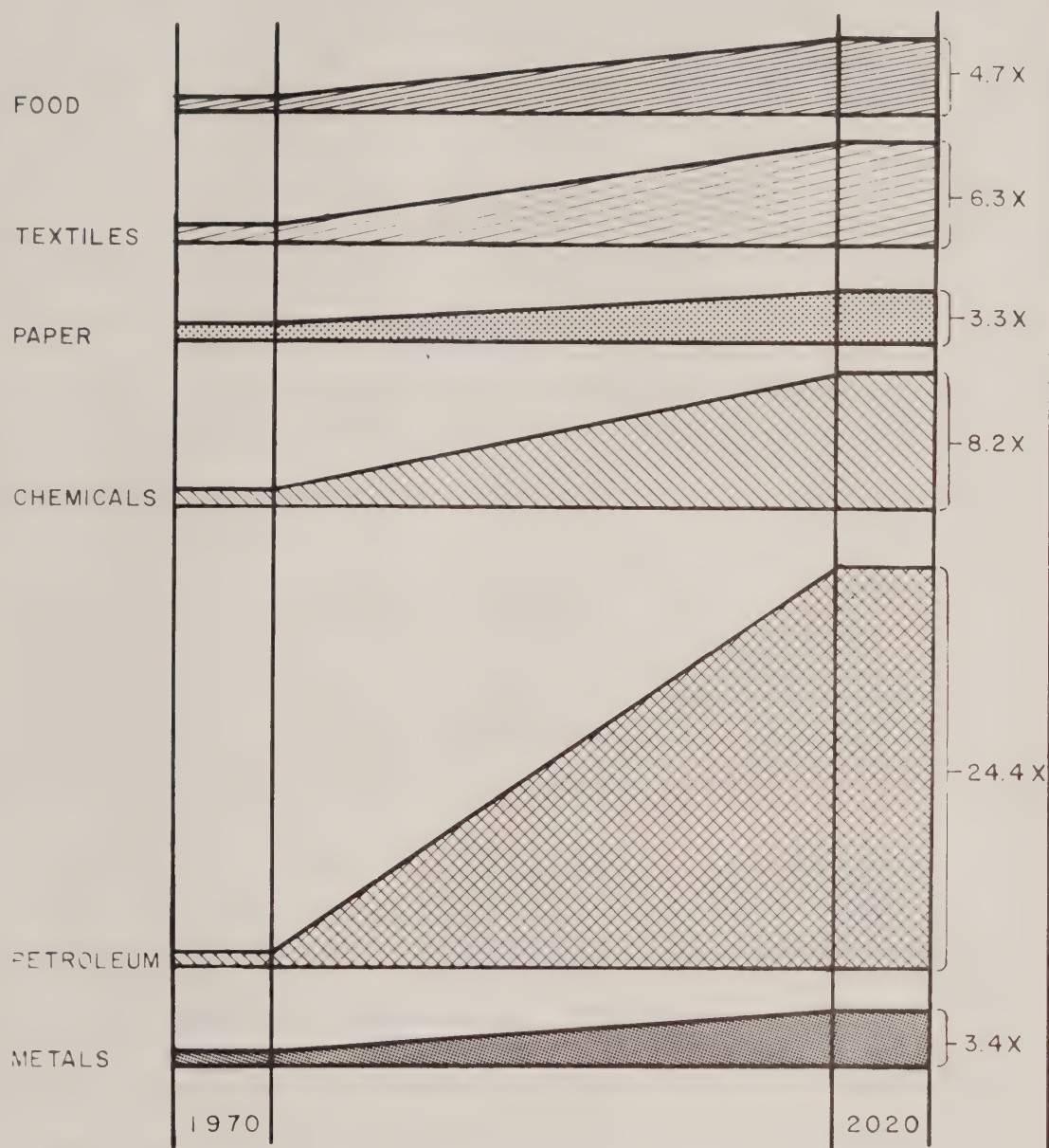
For each subregion, a textual description of its significant past trends is presented. Included in this discussion are population, urbanization, labor force, and industry activity trends. Analysis of the relationships among these variables in the subregion and comparisons to the entire region are also provided.

Probably the most significant factor in a subregion is the expectation for employment opportunities. As mentioned earlier, population settles or expands in a region primarily because of employment conditions. Employment developments not only affect the structural relationships in a subregion but also determine the overall size of the regional economy and its position in relation to other subregions.

PRESENT CONDITIONS

10. ECONOMIC SUBREGION I, LOWER CHARLES

The Lower Charles Subregion represents about 30 percent, geographically, of the entire Charles Watershed of 307 square miles. This area includes the towns and/or cities of Belmont, Boston, Brookline, Cambridge, Lexington, Newton, Somerville, Waltham, and Watertown. It is the industrial, commercial, and cultural heart of the region with the economy of its urban communities solidly based on a varied mix of manufacturing, commerce, education, government, and research and development.



PROPORTIONAL RISE IN ECONOMIC PRODUCTION
PER EMPLOYEE

FIGURE 4

a. Population.

Measured in terms of population, the Lower Charles is the largest subregion of the three. In 1965, over one million people resided here, representing 82.5 percent of the entire regional population (see Table B-6). Population density is also the highest here exceeding nine thousand persons per square mile in 1965.

Since 1950, however, population in the subregion has declined by almost 200 thousand persons, or roughly 15 percent. At the same time, population in the Middle and Upper Subregions has grown by 58.5 and 58.6 percent respectively, reflecting the Lower Charles' loss of population through net outmigration.

The Subregion's negative rates of population growth are also reflected in its decreasing percentage share of the total regional population. From a high of 93.2 percent of the total Charles population in 1910, the subregional share has declined to 82.5 percent by 1965. See Figure 5.

b. Urbanization and Population Density.

One of the earliest settled areas of the United States, the Lower Charles Subregion has for many years experienced a high level of urbanization. Intensive urban development characterizes virtually all of the Subregion and except for major public reservations, the whole area is densely built up.

Reflecting the high level of urbanization is the Subregion's 1965 average of 9,065 persons per square mile. Not only is this population figure higher than the entire regional average and those of the other subregions, but it is also higher than many county averages for the Boston/Washington Megalopolis. Although lower than the New York peak densities, the Subregion is in much the same density range as Washington, D. C., Baltimore, Philadelphia and Newark.

c. Employment

Compared with the other subregions, the employment pattern of the Lower Charles has centered somewhat less on manufacturing and somewhat more on transportation, communications, public utilities, finance, insurance, real estate, and the service industries (see Table B-7). Overall, the Lower Charles is a regional job

center mainly of nonmanufacturing positions. In 1963, only 27 percent of total employment in the Subregion was in manufacturing and this was concentrated mainly in electrical machinery and food and kindred products. The largest employing sector was wholesale and retail trade, comprising 31 percent of total employment followed by the services and then finance, insurance and real estate.

d. Communities.

(1) Boston.

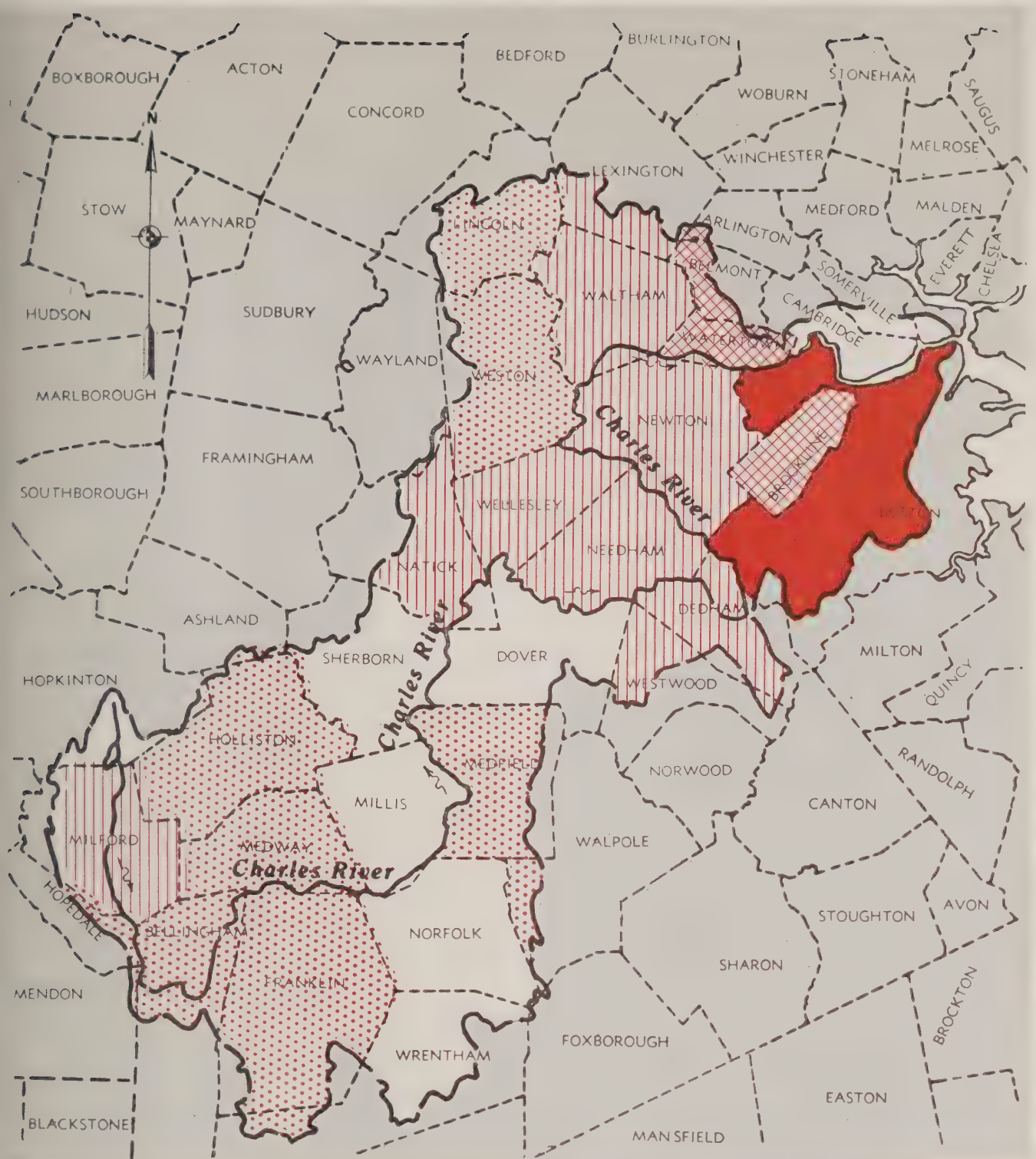
While Boston is only secondarily a manufacturing center, its product has a value added in excess of \$700 million annually and employs over 70 thousand people. The city's primary function in the region is as a trade and finance center with annual sales of its retail establishments exceeding one billion dollars.

Not only is Boston the economic center of the watershed, but it is the commercial and distribution center of New England as well. It is a major national and international air terminal and port, and the hub for New England's rail, truck, and bus services.

Traffic in the metropolitan area is serviced by an integrated rail and highway system. The Massachusetts Bay Transportation Authority operates a combination of rapid transit lines, surface street car lines and feeder bus routes to serve Boston and connect it to its suburbs.

Another important factor in Boston's economy is tourism, especially in the summer months. With a wealth of nationally famous shrines connected with early history - Bunker Hill Monument, the Old North Church, Faneuil Hall, and the U. S. S. Constitution to name but a few - the city is an attraction for tourists from throughout the country.

Finally, Boston's leading position in the educational field should be noted. Located in the city are two major colleges, Boston University and Northeastern University, the medical schools of Harvard University and Tufts University, and the Business Administration School of Harvard. Smaller colleges in the city include Simmons, Emanuel, Emerson, and the New England Conservatory of Music. Numerous specialty schools - business, art, accounting and the like - are also found as well as several junior and teacher's colleges.



CHARLES RIVER WATERSHED

NEW ENGLAND DIVISION, CORPS OF ENGINEERS



1970 AVERAGED RESIDENTIAL DENSITIES



(Approx. persons per gross square mile)

FIGURE 5

(2) Cambridge.

The city of Cambridge is in essence made up of two communities: an academic community housing two of the nation's major educational institutions, Harvard University and the Massachusetts Institute of Technology, existing side by side with one of the most heavily industrialized communities in Massachusetts. With only 7.14 square miles of land, the city is densely built over except for the college campuses.

Imposing in their physical plants, Harvard and M. I. T. occupy sizeable portions of the city's limited land area. The schools have developed aesthetically pleasing campuses, Harvard's in the very heart of the city and extending to the Charles, and M. I. T. 's lying along the Charles in the city's eastern section.

Lying generally to the east of the academic community is the city's industrial plant. Housed in mainly aging facilities are manufacturers of a wide variety of products ranging from candy to electronic components and from cameras to rubber belts for industry. While much of the product is regionally oriented as to market, producers for the national market are also located in the area. In 1963 over 25,000 people were employed by the manufacturing sector in Cambridge in more than 250 separate establishments with an annual product in excess of \$500 million.

(3) The Bedroom Communities.

The seven communities lying to the west of Boston and Cambridge in the Lower Subregion were in an earlier period mainly bedroom suburbs.

Today, Belmont, Brookline, and Lexington remain primarily residential suburbs of Boston. Characteristics of residential suburbs, the largest employing industry sectors in these communities are wholesale and retail trade and services.

While the city of Newton is also primarily a suburban residential community, its manufacturing industries, especially electronics, are of great significance. Following manufacturing, wholesale and retail trade, and the service industries, respectively, are the principal sources of employment.

Somerville, although a large bedroom community population-wise, has considerable industrial development and is also an important distribution center. Trade is the largest source of employment followed by manufacturing. Largest among manufacturing firms in importance are those engaged in the production and processing of food and kindred products.

The remaining communities in the Lower Subregion, Waltham and Watertown, are primarily diversified industrial cities. In both cities, manufacturing is by far the largest source of employment. In Waltham, the four leading manufacturing groups are electrical machinery, machinery (ex. elec.), professional and scientific instruments, and fabricated metal products.

11. ECONOMIC SUBREGION II, MIDDLE CHARLES

The Middle Charles Subregion, like the Lower, represents about 30 percent, geographically, of the entire Charles Watershed. This Subregion includes the Towns of Dedham, Dover, Lincoln, Natick, Needham, Sherborn, Wellesley, Weston and Westwood. For the most part, the Subregion is primarily residential, but with industry playing a part of growing significance in the economy.

a. Population.

Measured in terms of population, the Middle Charles Subregion is the second largest in the Watershed. In 1965, almost 145 thousand people resided in the Subregion, representing roughly 11 percent of the entire region's population (see Table B-6). Population density at 1,166 persons per square mile is slightly more than one-third the entire regional average, though well below that of the Lower Charles.

As opposed to the Lower Charles, however, the population in the Subregion has increased dramatically since the turn of the century by a factor of 4.5. Although much of the population growth was a result of an excess of births over deaths, most of the rise was due to a net immigration of persons. See Figure 6

The Subregion's positive rates of population growth are also reflected in the area's increasing percentage share of the total regional population. From a low of 3.4 percent of total population in 1910, the subregional share has increased to 10.9 percent by 1965.

PROJECTED POPULATION DENSITY CHARLES RIVER ECONOMIC SUB-REGIONS

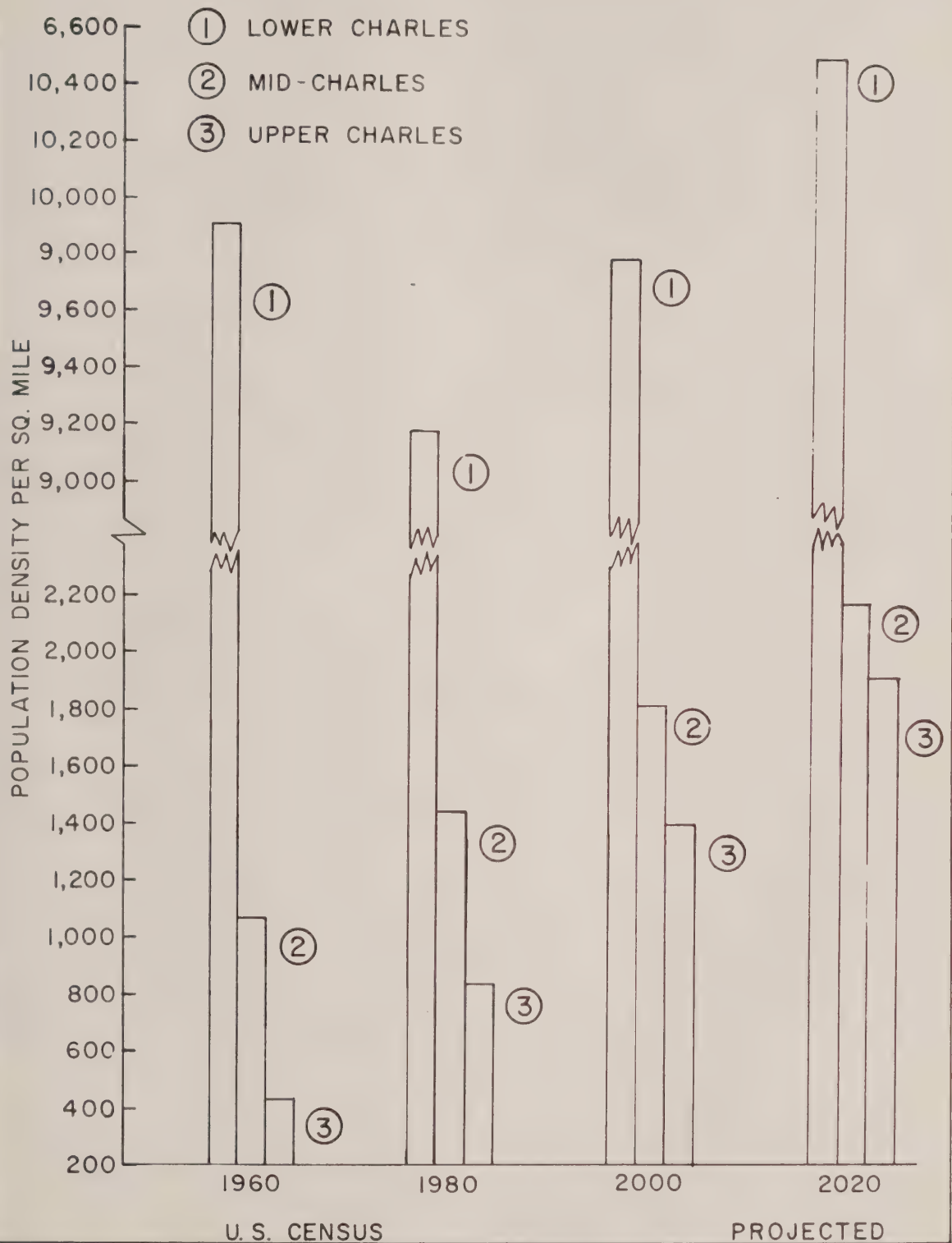


FIGURE 6

b. Urbanization and Population Density.

Less intensive urban development characterizes the highly residential Middle Charles Subregion than that of the more industrialized Lower Subregion. The prevailing dwelling structure types in the bedroom communities located in the Subregion are almost exclusively newer (post 1920) one-family wooden structures at much lower densities than in the Lower Charles. The exceptions to this pattern are older one-family and two-family wooden homes and brick apartments located in the larger population centers of Dedham, Natick, Needham and Wellesley. The sharply lower densities of these communities are evident when comparing the average number of persons per square mile of the Middle Subregion to the average figures for the Lower Subregion (see Table B-6b).

c. Employment.

Compared with the Lower Charles Subregion, the employment pattern of the Middle Charles has centered somewhat more on manufacturing, trade, and construction (see Table B-7b). As in the case of the Lower Subregion, the largest employing sector in 1963 was trade with 37.4 percent of all employment in the Middle Charles. Manufacturing was the next largest source of employment followed by the services.

d. Communities

(1) Dedham, Natick and Needham.

Measured in terms of population, Natick, Needham and Dedham were the largest communities in the Subregion in 1965. While all three are primarily residential bedroom communities with sizeable groups of persons commuting to jobs in the Lower Subregion, local industry occupies an increasingly important position. In both Dedham and Natick, the leading source of employment in 1963 was wholesale and retail trade with manufacturing running a close second followed by the services. In Needham, however, manufacturing was the leading source of employment followed by trade and services. This town is the site of a successful industrial-park type of development located in the Route 128 industrial belt around Boston.

(2) Lincoln, Wellesley and Weston.

Lincoln, Wellesley and Weston are residential communities placing high among the most desirable suburbs of Boston. Lincoln, with some farming in the area, has residential properties with the highest values of any in the Subregion. In Wellesley and Weston are found many fine estates and the homes of executives employed in the Lower Charles Subregion. In 1963, trade was the largest source of employment in Lincoln and Wellesley, and in Weston, the construction industry was the largest source of employment.

(3) Dover, Sherborn and Westwood.

Dover and Sherborn are semi-rural agricultural suburbs in the Boston metropolitan area. Although farming has been the principal industry in Dover, there have been many attempts at other industries. Westwood, primarily a residential town, and measured in terms of population the largest of the three, is an important suburb because of its proximity to Route 128 industrial belt and the Lower Charles industries.

12. ECONOMIC SUBREGION III, UPPER CHARLES

The Upper Charles Subregion is the largest in terms of land area, representing about 40 percent of the entire Charles Watershed. The Subregion includes the towns of Bellingham, Franklin, Holliston, Hopedale, Medfield, Medway, Milford, Millis, Norfolk and Wrentham. In terms of population, however, the combined town total is the smallest of any subregion.

a. Population.

In 1965, over 86 thousand persons resided in the Upper Charles Subregion; representing 6.5 percent of the entire regional population (see Table B-6). Population density at 536 persons per square mile is the lowest average for any subregion.

Like the Middle Charles, the population in the Upper Subregion has increased since the turn of the century, though not so sharply, by a factor of 2.6. Also similar to the Middle Subregion, most of this population growth was the result of a net immigration of persons.

The Subregion's positive rates of population growth are also reflected in the area's increasing percentage share of the total regional population. Although the increase has not been as great as that of the Middle Charles, the subregional share has almost doubled since 1920.

b. Urbanization and Population Density.

As mentioned earlier, the Upper Charles Subregion, although the largest geographically, is the least densely populated. For the most part, it is a residential, almost semi-rural, area with only three towns out of the ten having a population of over ten thousand persons.

c. Employment.

Compared with the other two subregions in the region, the employment pattern of the Upper Charles has centered more heavily on manufacturing and much less on trade, finance, insurance, real estate, and the service industries. Manufacturing is by far the largest source of employment providing over one-half the jobs in the Subregion (see Table B-7b). Trade is the second largest sector employment-wise followed by services.

d. Communities.

(1) Holliston, Medfield, Medway and Millis.

The northernmost towns in the Upper Charles Subregion, Holliston, Medfield, Medway and Millis are primarily residential communities bordering the Boston Metropolitan area. The manufacturing and trade sectors are the two largest sources of employment with some agricultural activity in Holliston and some industry centered in Millis.

(2) Milford and Hopedale.

Milford, the largest city in the Subregion, and Hopedale, the two westernmost communities in the Subregion, are both important manufacturing centers. Hopedale, with slightly over 95 percent of its total employment for 1963 in the manufacturing groups, is considered by some to be one of the most attractive of New England industrial villages.

(3) Bellingham, Franklin, Norfolk and Wrentham.

These four communities, all residential except for Norfolk which is primarily agricultural, border the Providence Metropolitan Area. Manufacturing is the leading source of employment followed by trade. Bellingham's moderate amount of manufacturing activity is heavily concentrated in the textile industry while Franklin has a more diversified industrial base, although textiles are also important. In addition to Wrentham's manufacturing activity, there is some summer resort business in the Lake Pearl area which is easily accessible to both the Boston and Providence Metropolitan Areas.

FUTURE PROSPECTS FOR SUBREGION GROWTH

13. FUTURE SUBREGION POPULATION GROWTH.

For future Charles River population growth, regional migration appears likely to be the dominant factor.

Although the Lower Charles Subregion has been declining as a population center and might show some further decline in the near future, its population is expected to stabilize by 1980. Because many of the institutions located in the Subregion have been well established over the years and closely identified with the local communities, they will not soon be duplicated, nor be relocated outside the area. So far as they are the work places of local residents, these primary economic institutions and all related secondary and tertiary activities will continue to draw and hold large numbers of persons in the existing stock of acceptable dwellings nearby. In some portions of the Lower Charles, Federally-aided urban renewal is replacing or enhancing that existing dwelling stock. In addition, state and municipal taxation policies, together with public and private investments in parks, water supply, sewerage, airport, seaport, motorways, rapid transit, health and educational institutions have established a framework for future private property development in the Subregion. Taken together, these developments demonstrate a likelihood of continuing population concentration in the area. Whatever the specific numbers, it may be speculated that about three-fourths of the future residents of the Charles River Watershed will continue to live in the Lower Charles

Subregion. The foregoing forecast is in part based on the huge concentration of metropolitan utilities and facilities already installed in the region, and the fact that these facilities and others to come are unlikely to be duplicated or removed.

As for the Middle Charles Subregion, no significant departure from the historical population trend is anticipated in view of open land availability. This Subregion will continue to gain in population at the expense of the Lower Charles as the country-wide trend of flight from the urban centers to the suburbs continues. The most immediate effect will continue to be felt in those Middle Watershed Communities which are closer to the core Boston area for commuting.

In the Upper Charles Subregion, and to some extent in the southernmost communities of the Middle Subregion, the single most significant factor affecting future development will be the recently constructed Interstate Route 495 expressway running generally north/south through the region. Although it is too early to assess its effects on the area, this regional transportation artery should increase the region's accessibility to and attractiveness for commercial and industrial development.

Related to this development is the population growth which is expected to be a concomitant of economic activity engendered by Route 495. Not only is this highway expected to attract new industry and population, but it will also enable the region's labor force to more readily seek employment outside the immediate area in the heavily industrialized Providence or Worcester metropolitan areas.

14. FUTURE URBANIZATION.

The influence and tendencies toward urban clustering in the Lower Charles appear likely to continue operative to the turn of the century and beyond. No technological, economic, social or political developments now in sight appear likely to introduce major changes in the mode, scale or location of urban development in the Subregion.

With the current pattern of expressway building and the choking of core urban areas by automobiles, there is both a continuing spread and recentralization of residents throughout the region. On the other hand, Federally-aided urban renewal has provided one impetus for continued clustering of residents in new high-rise residential and office buildings in the urban core area.

In the Middle and Upper Charles Subregions, the desire of property owners to control and protect their existing low density living conditions plus existing limitations on social overhead facilities is expected to inhibit the Lower Charles type of urban development. The prospects for many of these communities with open land availability is for accelerated suburban one-family building developments as the dispersion of metropolitan population continues.

15. FUTURE EMPLOYMENT.

In the past 40 years, most of the former eastern Massachusetts shoe manufacturing and textile industries have ceased operating in the Charles Watershed, particularly in the Lower Charles Subregion. Succeeding these have been large new employments in electronics, optics, instrumentation, office machines and publishing. Also of significant importance are growing employments in finance, insurance, real estate, government, and the service industries, especially in the Lower Charles. See Figure 7.

In the Middle and Upper Charles Subregions, greater employment opportunities in the newer growth industries are anticipated in view of improved highway connections with and those encircling the older urban core centers. Although these communities will remain primarily residential, the availability and cheapness of land relative to the older urbanized Lower Charles Subregion will continue to attract industry in areas specifically set aside and zoned for industrial activity. Here again, continuing employment declines in agriculture, textiles and leather are expected.

PERCENT EMPLOYMENT AND EARNINGS BY INDUSTRY IN THE CHARLES RIVER ECONOMIC AREA

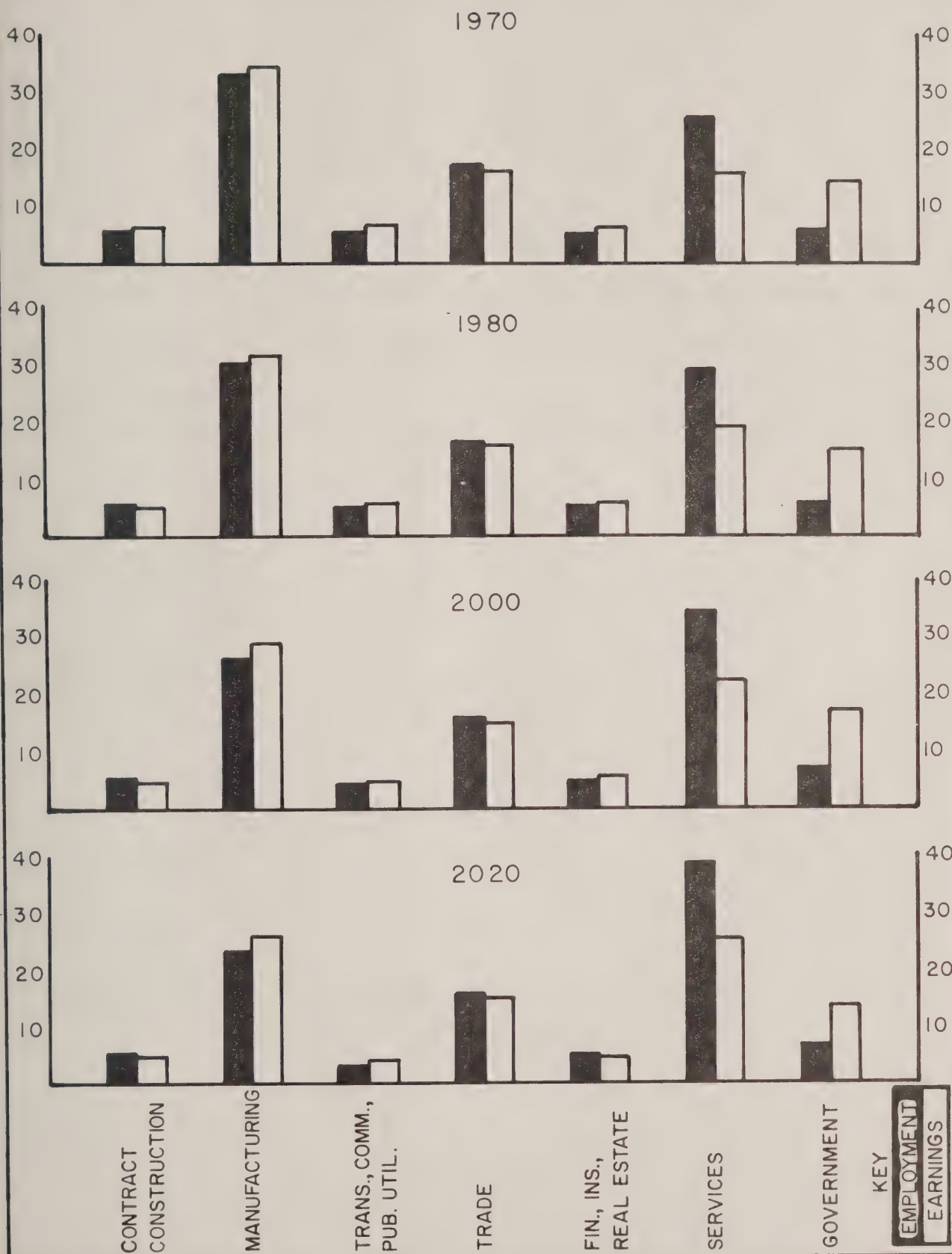


FIGURE 7

Table B-1

Total Population, United States, New England
and the
Charles River Economic Area, Selected Years

B-1a. Population

	<u>Actual</u>					<u>Projected</u>					
	<u>1929</u>	<u>1940</u>	<u>1950</u>	<u>1959</u>	<u>1962</u>	<u>1970</u>	<u>1980</u>	<u>1990</u>	<u>2000</u>	<u>2010</u>	<u>2020</u>
United States	122,107,000	132,456,000	151,871,000	177,124,000	185,860,000	205,051,000	234,193,000	269,746,000	306,757,000	348,894,000	397,562,000
New England	8,130,000	8,449,000	9,316,000	10,437,000	10,726,000	11,597,500	12,870,100	14,467,000	16,054,500	17,837,300	19,844,600
Charles River Economic Area	4,337,197	4,460,536	4,831,339	5,248,893	5,340,681	5,815,900	6,422,100	7,193,000	7,941,700	8,774,800	9,717,100

B-1b. Area's Population as Percent of U. S. and New England Population

Percent of U. S. Population	3.6	3.4	3.2	3.0	2.9	2.8	2.7	2.7	2.6	2.5	2.4
Percent of New England Population	53.3	52.8	51.9	50.3	49.8	50.1	49.9	49.7	49.5	49.2	49.0

B-1c. Average Annual Rates of Population Growth, Selected Periods

	<u>1929-62</u>	<u>1940-62</u>	<u>1950-62</u>	<u>1962-70</u>	<u>1970-80</u>	<u>1980-2000</u>	<u>2000-2020</u>	<u>1970-2020</u>
United States	1.28	1.56	1.71	1.25	1.34	1.34	1.31	1.33
New England	0.84	1.09	1.18	1.00	1.03	1.12	1.06	1.09
Charles River Economic Area	0.62	0.82	0.83	1.07	1.00	1.06	1.02	1.03

Table B-2
Personal Income, United States, New England, and the
Charles River Economic Area, Selected Years
(In Thousands of 1958 Constant Dollars)

	<u>Actual</u>					<u>Projected</u>					
	1929	1940	1950	1959	1962	1970	1980	1990	2000	2010	2020
United States	155,160,083	172,235,431	274,097,374	377,928,456	419,628,723	624,585,000	963,000,000	1,442,060,000	2,196,684,000	3,302,982,000	4,934,146,000
Per Capita	1,271	1,300	1,805	2,134	2,258	3,046	4,112	5,346	7,161	9,467	12,411
New England	12,759,101	13,868,129	17,986,738	24,091,810	26,849,386	38,041,179	55,275,721	79,857,473	117,766,295	173,342,101	251,922,210
Per Capita	1,569	1,641	1,931	2,308	2,503	3,280	4,295	5,520	7,335	9,718	12,695
Relative to U.S.	1.23	1.26	1.07	1.08	1.11	1.08	1.04	1.03	1.02	1.03	1.02
Charles River Economic Area	7,234,862	7,665,803	9,526,991	12,206,472	13,527,361	19,380,775	28,136,724	40,781,812	59,495,991	86,861,351	125,143,729
Per Capita	1,668	1,719	1,972	2,326	2,533	3,332	4,381	5,669	7,492	9,899	12,879
Relative to U.S.	1.312	1.322	1.093	1.090	1.122	1.09	1.07	1.06	1.05	1.05	1.04

B-2b. Area's Personal Income as Percent of U.S. and New England Income

Percent of U.S. Income	4.7	4.5	3.5	3.2	3.2	3.1	2.9	2.8	2.7	2.6	2.5
Percent of New England Income	56.7	55.3	53.0	50.7	50.4	50.9	50.9	51.1	50.5	50.1	49.7

B-2c. Average Annual Rate of Growth of Constant Dollar Personal Income

	<u>1929-62</u>	<u>1940-62</u>	<u>1950-62</u>	<u>1962-70</u>	<u>1970-80</u>	<u>1980-2000</u>	<u>2000-2020</u>	<u>1980-2020</u>
United States	3.00	4.12	3.62	5.12	4.37	4.25	4.12	4.12
New England	2.25	3.0	3.37	4.5	3.75	3.87	3.87	3.87
Charles River Economic Area	1.94	2.62	3.00	4.5	3.75	3.87	3.75	3.75

Table B-3

**Industrial Composition of Earnings Disbursements,
United States and Charles River Economic Area, Selected Years**

B-3a. Earnings (In Thousands of 1958 Dollars)

	<u>Actual</u>		<u>United States</u>					<u>Projected</u>			
	<u>1929</u>	<u>1940</u>	<u>1950</u>	<u>1959</u>	<u>1968</u>	<u>1970</u>	<u>1980</u>	<u>1990</u>	<u>2000</u>	<u>2010</u>	<u>2020</u>
Agr., For., & Fish	13,807,000	12,460,000	20,627,000	14,898,000	16,138,000	19,851,000	24,225,000	28,105,000	34,474,000	42,266,000	53,126,000
Mining	2,901,000	3,026,000	4,497,000	4,501,000	4,291,000	5,137,000	6,378,000	7,697,000	9,811,000	12,133,000	15,158,000
Contract Construction	6,658,000	5,389,000	13,534,000	19,102,000	20,096,000	30,180,000	44,512,000	64,150,000	95,378,000	140,578,000	206,818,000
Manufacturing	30,427,000	35,879,000	65,400,000	93,755,000	101,029,000	145,056,000	209,425,000	291,884,000	427,784,000	625,524,000	911,829,000
T.C.P.U.	11,922,000	12,264,000	18,471,000	23,944,000	25,083,000	33,679,000	44,969,000	58,641,000	82,496,000	115,913,000	163,835,000
Trade	22,425,000	27,936,000	42,779,000	55,507,000	59,061,000	84,796,000	123,618,000	177,473,000	263,858,000	388,855,000	572,234,000
F.I.R.E.	6,901,000	6,505,000	9,538,000	15,830,000	17,313,000	24,938,000	37,917,000	55,182,000	83,431,000	124,825,000	185,754,000
Services	15,470,000	17,493,000	25,266,000	39,550,000	45,987,000	69,584,000	124,965,000	210,823,000	346,955,000	555,946,000	867,917,000
Civilian Govt.	8,371,000	17,249,000	20,919,000	35,822,000	42,912,000	74,835,000	120,601,000	190,338,000	304,656,000	464,574,000	704,973,000
Fed. Military	468,000	1,103,000	5,146,000	8,576,000	8,999,000	10,109,000	12,548,000	16,263,000	21,425,000	28,191,000	37,110,000
Total Earnings	119,350,000	139,304,000	226,177,000	310,985,000	340,909,000	498,165,000	749,158,000	1,100,496,000	1,670,268,000	2,498,805,000	3,718,754,000

Charles River Economic Area

	<u>Actual</u>		<u>Projected</u>					<u>Projected</u>			
	<u>1929</u>	<u>1940</u>	<u>1950</u>	<u>1959</u>	<u>1968</u>	<u>1970</u>	<u>1980</u>	<u>1990</u>	<u>2000</u>	<u>2010</u>	<u>2020</u>
Agr., For., & Fish	103,060	100,577	161,509	108,427	105,550	142,600	168,900	221,500	261,300	309,400	377,200
Mining	6,747	3,076	5,395	8,449	8,102	8,000	8,800	9,700	11,300	12,900	15,000
Contract Construction	328,620	269,590	457,453	581,203	641,188	885,300	1,253,000	1,755,900	2,536,100	3,641,000	5,228,400
Manufacturing	2,012,206	1,983,695	3,055,370	3,765,225	4,019,601	5,559,600	7,561,300	9,960,100	14,057,000	19,560,100	27,245,500
T.C.P.U.	411,972	424,648	519,920	661,992	711,861	964,200	1,271,100	1,631,500	2,267,800	3,151,700	4,410,400
Trade	1,093,824	1,272,360	1,563,965	1,835,288	2,021,389	2,645,600	3,708,500	5,146,700	7,493,600	10,732,400	15,564,800
F.I.R.E.	336,496	331,024	394,013	627,206	686,828	917,200	1,319,900	1,810,000	2,608,900	3,734,800	5,336,700
Services	777,763	786,194	952,371	1,472,204	1,742,378	2,525,900	4,361,300	7,062,600	11,224,000	17,423,400	26,428,100
Civilian Govt.	410,036	809,101	783,718	1,154,545	1,368,156	2,266,000	3,532,400	5,396,100	8,499,900	12,636,400	18,752,300
Fed. Military	30,458	56,795	180,064	322,855	310,619	323,700	401,800	520,700	686,000	902,700	1,188,300
Total Earnings	5,511,182	6,037,060	8,073,778	10,537,394	11,615,672	16,238,200	23,587,000	33,514,800	49,645,900	72,104,600	104,546,500

B-3b. Percent Distribution Among Industries

	United States										
	<u>Actual</u>					<u>Projected</u>					
	<u>1929</u>	<u>1940</u>	<u>1950</u>	<u>1959</u>	<u>1962</u>	<u>1970</u>	<u>1980</u>	<u>1990</u>	<u>2000</u>	<u>2010</u>	<u>2020</u>
Agr., For., & Fish.	11.5	8.9	9.1	4.8	4.7	4.0	3.2	2.6	2.1	1.7	1.4
Mining	2.4	2.2	2.0	1.5	1.3	1.0	0.9	0.7	0.6	0.5	0.4
Contract Constr.	5.6	3.9	6.0	6.1	5.9	6.1	5.9	5.8	5.7	5.6	5.6
Manufacturing	25.5	25.7	28.9	30.1	29.6	29.1	27.9	26.5	25.6	25.0	24.5
T.C.P.U.	10.0	8.8	8.2	7.7	7.4	6.8	6.0	5.3	4.9	4.6	4.4
Trade	18.8	20.1	18.9	17.8	17.3	17.0	16.5	16.1	15.8	15.6	15.4
F.I.R.E.	5.8	4.7	4.2	5.1	5.1	5.0	5.1	5.0	5.0	5.0	5.0
Services	13.0	12.5	11.8	12.7	13.5	14.0	16.7	19.2	20.8	22.3	23.3
Civilian Govt.	7.0	12.4	9.2	11.4	12.6	15.0	16.1	17.3	18.2	18.6	19.0
Fed. Military	0.4	0.8	2.3	2.8	2.6	2.0	1.7	1.5	1.3	1.1	1.0
Total Earnings	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Charles River Economic Area

	<u>Actual</u>					<u>Projected</u>					
Agr., For., & Fish	1.9	1.7	2.0	1.0	0.9	0.9	0.7	0.6	0.5	0.4	0.4
Mining	0.1	0.1	0.1	0.1	0.1	-	-	-	-	-	-
Contract Const.	6.0	4.5	5.7	5.5	5.5	5.5	5.3	5.2	5.1	5.0	5.0
Manufacturing	36.5	32.8	37.8	35.7	34.6	34.2	32.1	29.7	28.3	27.1	26.1
T.C.P.U.	7.5	7.0	6.4	6.3	6.1	5.9	5.4	4.9	4.6	4.4	4.2
Trade	19.8	21.1	19.4	17.4	17.4	16.3	15.7	15.4	15.1	14.9	14.9
F.I.R.E.	6.1	5.5	4.9	5.9	5.9	5.6	5.6	5.4	5.3	5.2	5.1
Services	14.1	13.0	11.8	14.0	15.0	15.6	18.5	21.1	22.6	24.2	25.8
Civilian Govt.	7.4	13.4	9.7	11.0	11.8	14.0	15.0	16.1	17.1	17.5	17.9
Fed. Military	0.6	0.9	2.2	3.1	2.7	2.0	1.7	1.6	1.4	1.3	1.1
Total Earnings	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table B-4

**Employment by Industry Divisions, United States and
Charles River Economic Area, Selected Years**

B-4a. Employment by Industry Divisions

	United States								
	<u>Actual</u>	<u>Actual</u>	<u>Actual</u>	<u>Actual</u>	<u>Actual</u>	<u>Projected</u>	<u>Projected</u>	<u>Projected</u>	<u>Projected</u>
	<u>1940</u>	<u>1950</u>	<u>1960</u>	<u>1970</u>	<u>1980</u>	<u>1990</u>	<u>2000</u>	<u>2010</u>	<u>2020</u>
Agr., For., & Fish.	8,657,448	7,174,635	4,469,625	3,701,000	3,271,000	2,809,000	2,505,000	2,201,000	1,897,000
Mining	931,713	945,179	674,662	614,000	607,000	595,000	589,000	583,000	577,000
Contract Constr.	2,101,550	3,508,992	3,968,253	4,855,000	5,719,000	6,527,000	7,516,000	8,555,000	9,690,000
Manufacturing	10,757,970	14,801,078	18,244,900	20,958,000	23,392,000	25,596,000	28,275,000	31,152,000	34,366,000
T.C.P.U.	3,173,444	4,513,645	4,650,643	4,859,000	5,149,000	5,389,000	5,413,000	5,480,000	5,602,000
Trade	7,683,922	10,739,659	12,287,854	14,261,000	16,483,000	18,545,000	20,834,000	23,267,000	25,953,000
F.I.R.E.	1,494,983	1,947,942	2,820,517	3,538,000	4,319,000	5,058,000	6,054,000	7,088,000	8,203,000
Services	8,757,015	10,255,317	14,123,667	19,863,000	26,268,000	32,526,000	41,179,000	50,065,000	59,529,000
Civilian Govt.	1,508,208	2,550,752	3,341,911	4,444,000	5,712,000	7,073,000	8,506,000	9,958,000	11,569,000
Fed. Military	309,562	1,037,713	1,790,617	1,861,000	1,792,000	1,792,000	1,792,000	1,792,000	1,792,000
Total Employment	45,375,815	57,474,912	66,372,649	78,954,000	92,712,000	105,910,000	122,663,000	140,141,000	159,178,000
Participation Rate (Emp./Pop.)	.3433	.3798	.3701	.3850	.3950	.3926	.3998	.4016	.4003

Charles River Economic Area

	Charles River Economic Area								
	<u>Actual</u>	<u>Actual</u>	<u>Actual</u>	<u>Actual</u>	<u>Actual</u>	<u>Projected</u>	<u>Projected</u>	<u>Projected</u>	<u>Projected</u>
	<u>1940</u>	<u>1950</u>	<u>1960</u>	<u>1970</u>	<u>1980</u>	<u>1990</u>	<u>2000</u>	<u>2010</u>	<u>2020</u>
Agr., For., & Fish.	47,086	43,605	29,503	24,800	21,500	18,900	16,800	14,800	12,700
Mining	1,538	1,491	1,370	1,000	800	800	700	600	600
Contract Constr.	80,144	114,489	118,847	141,400	160,400	178,200	199,800	221,700	245,700
Manufacturing	651,787	764,861	823,329	828,400	860,900	891,600	929,100	974,000	1,027,000
T.C.P.U.	108,435	140,336	130,290	134,300	140,200	144,700	143,400	143,400	145,100
Trade	318,968	388,895	395,048	435,500	486,900	534,000	585,300	639,400	698,700
F.I.R.E.	66,645	83,326	107,593	123,300	142,700	159,700	183,600	297,300	232,100
Services	346,841	366,301	470,281	642,200	823,500	983,300	1,211,900	1,438,400	1,673,400
Civilian Govt.	67,843	100,053	116,078	145,600	175,800	207,000	241,600	273,800	307,700
Fed. Military	8,122	35,701	66,416	54,400	52,400	52,400	52,400	52,400	52,400
Total Employment	1,697,129	2,039,058	2,258,755	2,530,900	2,865,200	3,170,500	3,564,600	3,965,800	4,395,500
Participation Rate (Emp./Pop.)	.357	.394	.398	.400	.410	.410	.410	.410	.410

B-4b. Percent Distribution of Employment by Industry Divisions

United States									
	<u>Actual</u>			<u>Projected</u>					
	<u>1940</u>	<u>1950</u>	<u>1960</u>	<u>1970</u>	<u>1980</u>	<u>1990</u>	<u>2000</u>	<u>2010</u>	<u>2020</u>
Agr., For., & Fish	19.1	12.5	6.7	4.7	3.5	2.6	2.0	1.6	1.2
Mining	2.1	1.6	1.0	0.8	0.6	0.5	0.5	0.4	0.4
Contract Constr.	4.6	6.1	6.0	6.1	6.2	6.1	6.1	6.1	6.1
Manufacturing	23.7	25.8	27.5	26.5	25.2	24.1	23.1	22.2	21.6
T. C. P. U.	7.0	7.9	7.0	6.1	5.6	5.1	4.4	3.9	3.5
Trade	16.9	18.7	18.5	18.1	17.8	17.5	17.0	16.6	16.3
F. I. R. E.	3.3	3.4	4.3	4.5	4.7	4.8	4.9	5.1	5.1
Services	19.3	17.8	21.3	25.2	28.3	31.0	33.6	35.7	37.4
Civilian Govt.	3.3	4.4	5.0	5.6	6.2	6.6	6.9	7.1	7.3
Fed. Military	0.7	1.8	2.7	2.4	1.9	1.7	1.5	1.3	1.1
Total Employment	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Charles River Economic Area

	<u>Actual</u>			<u>Projected</u>					
Agr., For., & Fish.	2.8	2.1	1.3	1.0	0.8	0.6	0.5	0.4	0.3
Mining	0.1	0.1	0.1	--	--	--	--	--	--
Contract Constr.	4.7	5.6	5.3	5.6	5.6	5.6	5.6	5.6	5.6
Manufacturing	38.4	37.5	36.4	32.7	30.1	28.1	26.1	24.6	23.3
T. C. P. U.	6.4	6.9	5.8	5.3	4.9	4.6	4.0	3.6	3.3
Trade	18.8	19.1	17.5	17.2	17.0	16.9	16.4	16.1	15.9
F. I. R. E.	3.9	4.1	4.8	4.9	5.0	5.0	5.1	5.2	5.3
Services	20.4	18.0	20.8	25.4	28.7	31.0	34.0	36.3	38.1
Civilian Govt.	4.0	4.9	5.1	5.8	6.1	6.5	6.8	6.9	7.0
Fed. Military	0.5	1.7	2.9	2.1	1.8	1.7	1.5	1.3	1.2
Total Employment	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table B-5

Charles River Economic Area
Economic Production per Employee
(1958 Dollars)

Industry	1960	1970	1980	1990	2000	2010	2020
Food	6,952	10,053	14,357	19,378	25,997	35,107	47,750
Textiles	4,602	7,353	10,921	15,714	22,680	32,438	46,262
Paper	7,365	10,170	13,106	16,576	21,051	26,542	33,804
Chemicals	9,232	16,287	26,295	41,148	68,124	97,891	133,356
Petroleum	7,573	20,623	42,297	81,856	155,240	280,181	502,761
Primary Metals	9,322	13,207	17,333	22,015	27,670	35,011	45,346

Table B-6

Population, Charles River Subregions,
Selected Years

	1900	1910	1920	<u>B-6a. Population</u>		1950	1955	1960	1965
				1930	1940				
Charles River Total	887,579	1,058,851	1,185,717	1,320,897	1,335,818	1,439,320	1,375,488	1,399,374	1,326,579
Lower Subregion	822,134	986,934	1,104,118	1,216,063	1,219,032	1,293,176	1,204,162	1,196,949	1,094,888
Middle Subregion	32,245	36,362	42,042	60,069	68,076	91,444	112,352	133,444	144,942
Upper Subregion	33,200	35,555	39,557	44,765	48,710	54,700	58,974	68,981	86,749

B-6b. Population Density, Persons per Square Mile

Charles River Total	2,182	2,603	2,915	3,247	3,284	3,539	3,382	3,440	3,261
Lower Subregion	6,806	8,171	9,141	10,067	10,092	10,706	9,969	9,909	9,064
Middle Subregion	259	293	338	483	548	736	904	1,074	1,166
Upper Subregion	205	220	245	277	301	338	365	427	536

B-6c. Subregion Population
as Percent of Total Population

Lower	92.6	93.2	93.1	92.1	91.3	89.8	87.5	85.5	82.5
Middle	3.6	3.4	3.5	4.5	5.1	6.4	8.2	9.5	10.9
Upper	3.7	3.4	3.3	3.4	3.6	3.8	4.3	4.9	6.5

B-6d. Average Annual Rates of Population GrowthCharles River Subregions, Selected Periods

	<u>1920-65</u>	<u>1940-65</u>	<u>1950-65</u>	<u>1950-55</u>	<u>1955-60</u>	<u>1960-65</u>
Charles River Total	0.25	Neg.	Neg.	Neg.	0.34	Neg.
Lower Subregion	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.
Middle Subregion	2.78	3.06	3.12	4.12	3.50	1.67
Upper Subregion	1.75	2.34	3.12	1.53	3.12	4.62

Table B-7

Employment by Industry Division in Charles River
Subregions, 1963

B-7a. Employment by Industry Divisions

	<u>Charles River Totals</u>	<u>Lower Charles</u>	<u>Middle Charles</u>	<u>Upper Charles</u>
Agriculture & Mining	2,197	1,795	322	80
Construction	34,732	30,456	3,363	913
Manufacturing	162,313	143,729	10,417	8,167
Trans., Comm. & Pub. Utilities	48,576	47,198	834	544
Trade	180,496	164,801	12,785	2,910
Fin., Ins., & Real Estate	65,287	63,362	1,728	197
Services	84,897	79,025	4,762	1,110
Total Employment	578,498	530,366	34,211	13,921

B-7b. Percent Distribution of Employment
by Industry Divisions

Agriculture & Mining	0.4	0.3	0.9	0.6
Construction	6.0	5.7	9.8	6.6
Manufacturing	28.0	27.1	30.5	58.6
Trans., Comm. & Pub. Utilities	8.4	8.9	2.4	3.9
Trade	31.2	31.1	37.4	20.9
Fin., Ins., & Real Estate	11.3	12.0	5.1	1.4
Services	14.7	14.9	13.9	8.0
Total	100.0	100.0	100.0	100.0

WATER RESOURCES INVESTIGATION

CHARLES RIVER STUDY

APPENDIX C

FLOOD PLAIN MANAGEMENT

PREPARED BY

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASSACHUSETTS

DECEMBER 1971

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FLOOD PLAIN MANAGEMENT
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APPENDIX C

FLOOD PLAIN MANAGEMENT

1. INTRODUCTION

The magnitude of future flood damage and loss of life will likely be determined primarily by the nature and extent of development in flood plains. Structural measures, currently in use to prevent flood losses, will continue to do so. However, in many cases, additional structural measures are not feasible, economically justified, or politically acceptable. The alternative is non-structural measures, or more properly identified as Flood Plain Management.

Flood plains often have high value uses other than commercial, residential, industrial, or public development subject to flood damage. In many instances, the valley storage acts as a natural reservoir, thereby reducing downstream flood damage. Flood plains can be of value for a variety of outdoor recreation activities, are highly scenic, and provide ribbons of green and open space in both rural and urban areas. Stream and associated wetlands constitute critical fish and wildlife habitat, often to the degree that preservation of wetlands is fully justified for these purposes quite apart from flood damage.

2. FLOOD PROBLEMS

When Congress declared flood control a Federal responsibility in the 1936 Flood Control Act, yearly damages throughout the country were averaging over 200 million dollars (1960 dollars). Since that time, at least 7 billion dollars have been spent in the construction and operation of engineering and associated land-treatment works to reduce or curb flood flows. Flood warning services extended by the National Weather Service have resulted in Federal expenditures of almost 16 million dollars during 1959 - 1966. In addition, relief and rehabilitation operations by Federal agencies have grown in volume so that in the last few years, the mean annual outlay has been in excess of 25 million dollars.

With these investments, it might be expected that the mean annual flood loss would decline drastically and the problem would be diminished. Statistics do not bear this out. Based on the current status of flood control works and projected conditions of flood plain use and development, the total annual flood damage potential for the nation is anticipated to increase from 1.7 billion dollars in 1966, to 3.5 billion in the year 2000, and 5.0 billion dollars in 2020.

Our agricultural nation of a few decades ago has developed into an urban industrial society. As urban functions become more and more decentralized, the flood hazard areas, because of terrain and building conditions, attracted extensive urban investment. These investments occurred in hazard areas along the coasts, the larger streams and even in the headwaters of the smallest tributaries.

As more and more protection is provided, the calculated risk of occupying flood plains is correspondingly reduced. This attracts to these areas much new industry and habitation which would not have been located there had the flood works not existed, and mushrooming new construction tends to spread beyond the protection limits of existing facilities. Excellent examples of these unwise developments can be found in all the New England States.

People, often without realizing the risk, are constructing new developments in flood-prone areas and are reducing the hydraulic efficiency of river channels. Examples can be found in almost every river-side community. Flood hazards are thereby increased and the effectiveness of existing flood control works is correspondingly diminished. Hence, a relatively minor flood in historic terms may cause far greater damage in the built-up flood plain.

A good example of this is the recent flood of March 1968. Civil Defense officials of the Commonwealth of Massachusetts the experienced loss of private property and services may have exceeded 100 million dollars. On the basis of a few samples, it has been estimated that at least 25 percent and possibly 50 percent of the damages were experienced in new construction built since the last major flood of August 1955.

The cure for our flood problem is twofold. Either keep the river away from development, or keep development away from the river. Flood plain management follows the latter course of action.

Although the solution to flood damage prevention appears elementary, the implementation of such a program is complex. Here in New England, where water power was a necessary part of our industrial heritage, many of our larger communities were located along and often spanned our major water courses. As transportation needs developed, our railroads and highways sought the least expensive routes which paralleled the river valleys. In these highly developed areas, flood plain regulations can do little to improve the flood damage problems. But by preventing new encroachments on the rivers, flood plain regulations can prevent a deterioration of the situation and a repetition of the problem in less developed areas.

3. WHAT HAS BEEN DONE

a. General

For more than a decade, officials, planners and engineers have looked for alternatives and supplements to the historical flood control approach. Alternatives available for managing our flood plains include both corrective and preventative measures as shown in Figure C-1. Several studies and reports by State and Federal Agencies, as well as action by the Congress, document the increasing awareness of the need for wise judgment in the use of our flood plain resources.

b. Massachusetts State Program

Between 1963 and 1968, the General Court of Massachusetts enacted four statutes to control the alteration of the Commonwealth's coastal and inland wetlands (General Laws, Ch. 130, Secs. 27 and 105, and Ch. 131, Secs. 40 and 40A). Coastal wetlands include "low lands subject to tidal action or coastal storm flowage" (G. L., Ch. 130, Sec. 105). Inland wetlands include "any marsh or swamp subject to flooding by fresh water" (G. L., Ch. 131, Secs. 40 and 40A).

Thus the Department of Natural Resources can act directly, through the issuance of restrictive orders on particular wetland areas, to restrict development of many areas of high flood hazard. The key mechanism of the wetlands acts is compensable regulation; if a land-owner objects to the effects of a restrictive order on his land use intentions, he can object and oblige the Department to choose between (a) modifying the order, (b) retracting the order, or (c) acquiring the land or a sufficient easement therein by purchase or eminent domain proceedings.

The Department of Natural Resources is hopeful that many land-owners will accept its regulations as serving their own long-range interests. Detailed technical studies are prerequisites to the adoption of sound restrictive orders, and increased efforts to delineate flood plains are a major element of such studies.

Using aerial photogrammetric techniques, the Department of Natural Resources has identified the swamps and marshes in the eastern 2/3 of the Charles River watershed. This information has been transferred to ownership maps maintained by town assessors, and hearings are being held in individual towns as provided by the Inland Wetlands Act. This material is also available for the use and information of towns lying within the 200 square mile area thus far delineated.

The zoning enabling act (G. L., Ch. 40A) authorizes towns to consider flood hazard areas in zoning codes. To date, 13 communities in the watershed (see Table C-1) have adopted flood plain zoning or conservancy districts and the list is slowly growing longer.

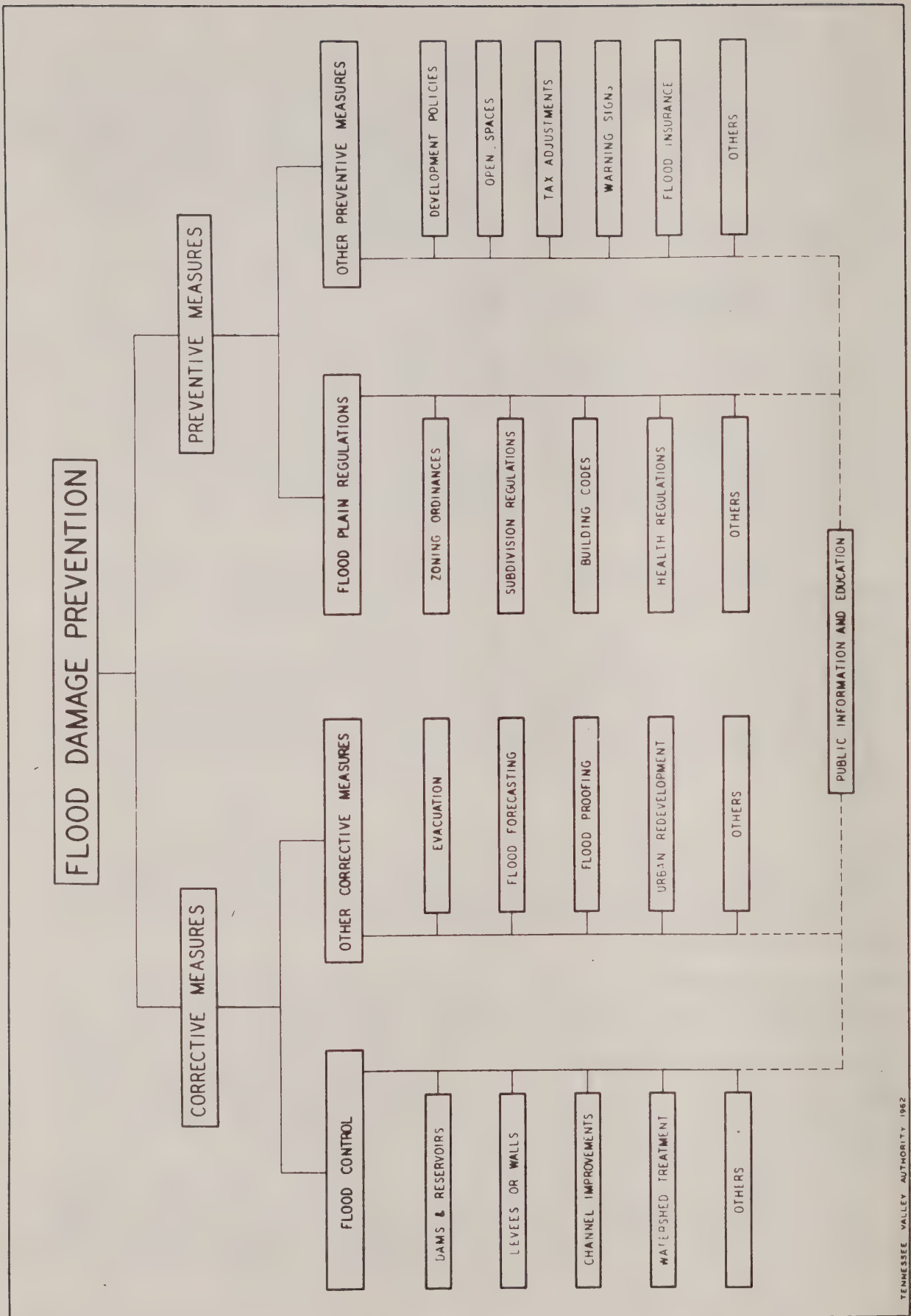
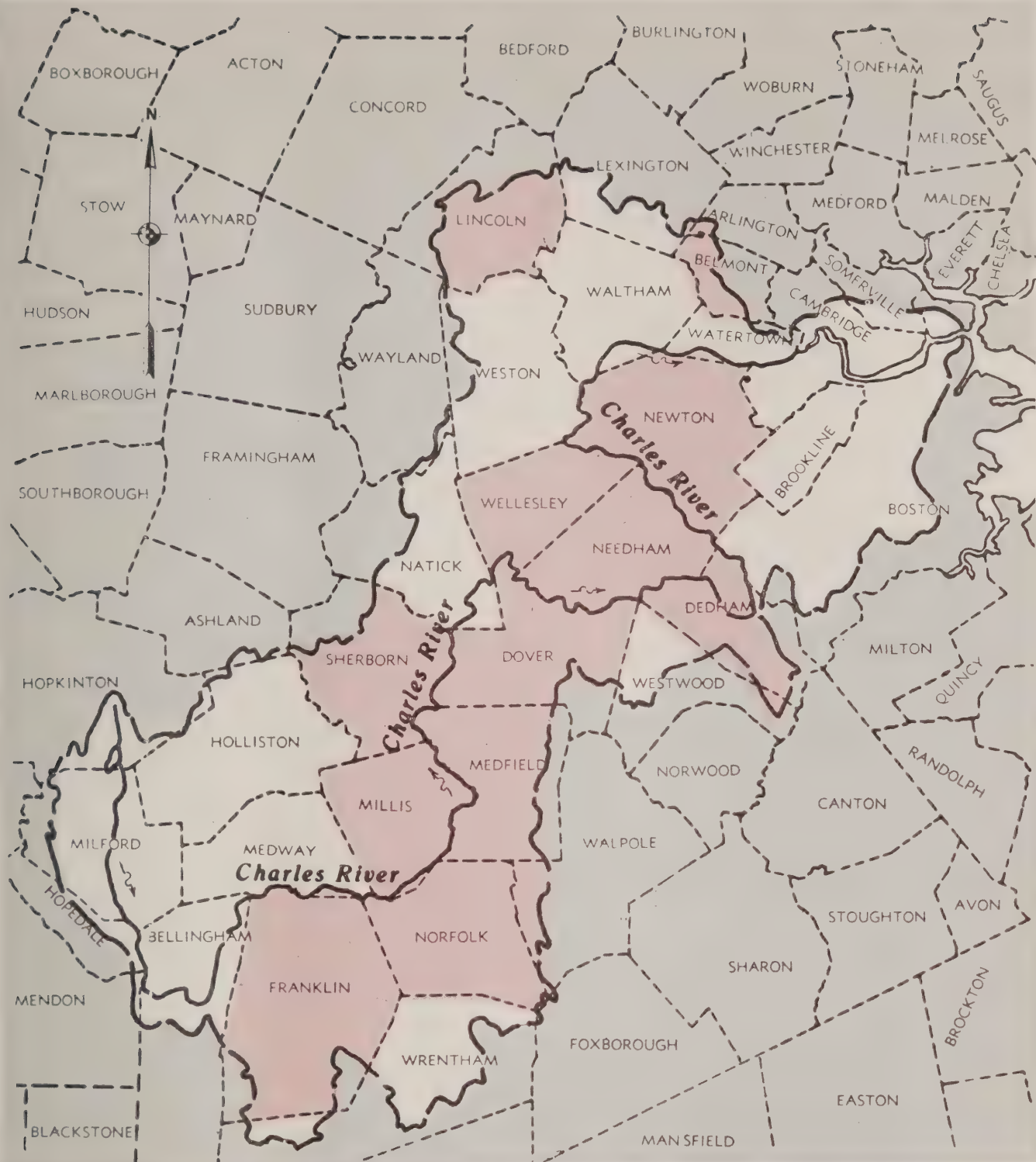


Figure C-1

TABLE C-1
CHARLES RIVER STUDY
COMMUNITIES
WITH
FLOOD PLAIN ZONING OR CONSERVANCY ZONINGS

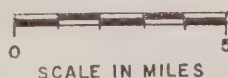
City or Town	Percent of Area in Charles R. Watershed	Frontage on Charles River		Frontage on Principal Tributaries			City or Town Flood Plain Zoned		Flood Plain Zoning Adopted	Conservancy Zoning Adopted
		Left	Right	Name	Left	Right	Area Acres	Elevations MSL.		
		Bank Miles	Bank Miles		Bank Miles	Bank Miles				
1. Ashland	4.3									
2. Arlington	6.3									
3. Bellingham	42.0	8.78	6.50	Hopping Brook	0.4	0.4				
				Beaver Brook	1.4	1.4				
4. Belmont	40.0									Yes
5. Boston	57.2	0.87	10.44	Muddy River	0.0	2.2				
6. Brookline	100.0			Muddy River	2.2	0.0				
7. Cambridge	64.6	6.13					416	95	Yes	
8. Dedham	66.9	6.17	6.87	Mother Brook						
				Diversions	0.1	0.1				
9. Dover	85.5		10.77	Trout Brook	2.0	2.0				Yes.
10. Foxboro	0.1									
11. Franklin	90.7		4.41	Shepard Brook	1.5	1.5	2,450	Varies	Yes	
				Mine Brook	5.0	5.0				
12. Holliston	99.5			Bogastow Brk	2.9	3.0				
				Chicken Brk	4.1	4.1				
				Hopping Brk	4.0	4.0				
13. Hopedale	18.8		1.77							
14. Hopkinton	10.2	0.26	0.26							
15. Lexington	29.5									Yes
16. Lincoln	61.3			Stony Brook	3.0	3.0			Yes	Yes
17. Medfield	78.1		9.06	Stop River	2.0	2.0	1,415	125		
18. Medway	100.0	5.78	1.17	Chicken Brk	3.3	3.3				
				Hopping Brk	2.2	2.2				
19. Mendon	1.6		0.91							
20. Milford	86.3	5.64	4.90	Lake Louisa						
				Outlet	0.3	0.3				
21. Millis	100.0	10.27	1.61	Bogastow Brk	4.5	4.5	1,280	125	Yes	
22. Natick	55.2	2.95	2.87	Davis Brook	2.0	2.0				
				Indian Brook	1.8	1.0				
23. Needham	100.0	11.93		Fuller Brook	1.5	1.5	672	Varies	Yes	
24. Newton	100.0		11.88						Yes	Yes
25. Norfolk	99.7		2.04	Mill River	1.5	1.5	800	Varies	Yes	Yes
				Stop River	2.0	1.0				
26. Sherborn	83.4	4.65		Indian River	0.5	1.5	343	125	Yes	
				Farm Pond						
				Outlet	0.5	0.5				
				Sewall Brk	3.0	3.0				
				Bogastow Brk	0.1	0.0				
27. Somerville	33.9									
28. Walpole	1.0			Stop River	0.0	1.0			Yes	
29. Waltham	100.0	3.21	2.72	Stony Brk	2.0	0.0				
30. Watertown	86.3	4.47	0.70							
31. Wayland	2.6									
32. Wellesley	100.0	5.24		Waban Brk	0.5	0.5			Yes	Yes
				Fuller Brk	2.8	2.8				
33. Weston	91.0	2.59		Stony Brk	2.5	4.7				
34. Westwood	34.0		0.06							
35. Wrentham	43.4									

NOTES: Left or Right bank designations are moving from source to mouth.
Principal tributaries are limited to non-urban waterways
Areas of flood plain zoning are based on approximate measurements on USGS Maps 1" = 2,000



CHARLES RIVER WATERSHED

NEW ENGLAND DIVISION, CORPS OF ENGINEERS



**COMMUNITIES WITH
FLOOD PLAIN ZONING
OR CONSERVANCY ZONINGS**

FIGURE C-2

"In August of 1971 a Joint Coordination Agreement for Flood Hazard Analysis and Flood Plain Studies was signed between the Massachusetts Water Resources Commission and the USDA, Soil Conservation Service. This agreement outlines the responsibilities of each of these agencies in conducting cooperative flood plain and flood hazard studies within the Commonwealth of Massachusetts."

c. Federal Programs

(1) Federal Policy - A Task Force on Federal Flood Control Policy was appointed late in 1965 to study the flood situation in the United States and recommend action to alleviate flood losses that are affecting the national economy. The Task Force submitted a report drawing upon the combined experience and judgment of the Corps of Engineers, Department of Agriculture, Department of the Interior, Tennessee Valley Authority, State and local agencies and outside experts for providing guidance in dealing with flood losses by a wide variety of means. The Task Force Report, entitled, "A Unified National Program for Managing Flood Losses", was published in August 1966 as House Document No. 465, 89th Congress, 2nd Session. It stressed five basic actions which can and should be immediately undertaken by the Federal Government. These were:

- (a) To improve the basic knowledge about the flood hazard.
- (b) To coordinate and better plan for new developments on the flood plain.
- (c) To initiate a program of technical information and services to managers of flood plain properties.
- (d) To move ahead with studies aimed at a practical national program for flood insurance.
- (e) To adjust, through Executive action and legislation, Federal flood control policy to sound criteria and changing needs.

The Task Force proceeded to make 16 recommendations which would achieve the goals outlined above. The following are the recommendations in H. D. 465 and a current status for each as related to the New England area:

Recommendation 1 - A three-stage program to delimit major flood hazards should be initiated by the Corps of Engineers, the Geological Survey, and other competent agencies.

The intent of this recommendation was to develop an immediate although rough national survey of problem areas and to accelerate detailed reports. The three phases were:

(a) Listing of towns and streams with flood problems - This has been completed. A list of all "urban places" (as classified in the 1960 Census of Population) with a population of 2,500 or more was prepared in December 1966 and revised in July 1967. In New England, there are about 350 urban areas that have a flood problem of some degree. Consideration has been given to preparing a similar list for communities with less than 2,500 population but more than 500. However, no action has been taken to date. Of the 35 communities in the Charles River watershed, 25 are listed as having a flood problem.

(b) Outlining of flood plains on maps or aerial photographs - This would delimit areas occasionally inundated by river or coastal waters without definition of the frequency and magnitude of flooding. This responsibility was assigned to the U. S. Geological Survey which published guidelines to its field personnel in May 1967 and began to initiate its program. The District Offices of the USGS in Boston, Massachusetts, and Hartford, Connecticut, received funds in FY 1969 and have prepared many of the maps. These serve to provide only a quick and general appraisal of flood-prone areas to give local agencies advanced information for use in their planning functions.

It should be noted that the U. S. Geological Survey has been publishing detailed flood inundation maps and profiles as Hydrologic Atlases since 1959. These atlases, requested by local interests, are financed under a 50-50 share program with the Federal Government. To date, most of the requests for the programs have been generated in the mid-western part of the country with none from New England.

The USGS District Office in Boston has prepared aerial mosaics delineating the extent of flooding and flood profiles as experienced in March 1968 for the Charles River. They are also in the process of preparing the same type of information for the Blackstone, Concord, Ipswich, Neponset, Sudbury, Taunton, and Wading Rivers. The profile data is being supplied by the Corps of Engineers, Soil Conservation Service and the Commonwealth of Massachusetts.

(c) Accelerating the present program of flood hazard information reports - These reports include maps or mosaics, profiles, charts, and tables and a narrative describing the extent, depth, probability and duration of past floods and those that may be expected in

the future. These reports, requested by local agencies, are to be used in developing regulations and policies for wise development in flood plains to reduce the potential for damage.

(2) Corps of Engineers - Under Section 206 of the 1960 Flood Control Act (P. L. 86-645), the Corps of Engineers has initiated this program in New England. To date twenty-three reports, covering fifty-one communities have been prepared. One of these reports was prepared for Medway.

Plans, profiles, and river cross sections of a typical Flood Plain Information Report are shown in Exhibit C-1.

The intent of the recommendation to accelerate the program to cover all of the urban areas within a 10-year span. On the basis of present budgeting, indications are it will take about 15 years to complete the detailed studies for the 350 urban areas in New England. But, there are many areas on major streams where the Corps of Engineers has compiled data, in the course of its flood control studies which are being used by communities to develop preliminary guidelines.

(3) Soil Conservation Service - The Soil Conservation Service has a variety of data which might be useful in delineating flood-prone areas. The details and intensity of the data vary from a type which can be used to develop frequency floodlines to other data that are considered to have only flood hazard warning value. The following summarizes the types of information that is available.

(a) Studies used in developing the Watershed Work Plans contain data in the damage reaches, from which floodlines for certain frequencies of flooding can be established. The more recently prepared Watershed Work Plans have included in them aerial photos which show floodlines. These are usually only for urban areas where significant flood damages are involved.

(b) Appendix F is an abridged version of the Charles River Study Area Report prepared under the Massachusetts Water Resources Study (Type IV, River Basin). This study is a cooperative endeavor by the U. S. Department of Agriculture and the Massachusetts Water Resources Commission. Some of the items studied in upstream watersheds of the Commonwealth are: identification of potential reservoir sites; appraisal of damage from floodwater, sediment and erosion; present and projected land use; fish and wildlife, recreation, water supply, water quality, and identification of flood plains and wetlands.

(c) Soil surveys provide valuable data that can be used as a guide in initial delineation of flood plains. They are inventories of the major physical and chemical characteristics of soil. Generally, soil surveys delineate soils that are subject to frequent flooding and soils that are subject to occasional flooding. Soil survey data cannot be used to predict flooding frequency for specific flood plains. It does, however, identify landscape positions that are, or have been, subject to flooding. Published soil surveys include a text and maps which describe and show the locations of these alluvial soils. Similar unpublished soil survey data is available for many flood plains. Information on published or unpublished soil survey data is available through the SCS State Offices. Locations where soil survey data is available are discussed in Appendix F.

Recommendation 2 - A uniform technique of determining flood frequency should be developed by a panel of the Water Resources Council.

This has been accomplished by the Hydrology Committee of the Water Resources Council and published as Bulletin 15, dated December 1967, entitled, "A UNIFORM TECHNIQUE OF DETERMINING FLOOD FLOW FREQUENCIES".

Recommendation 3 - A new national program for collecting more useful flood damage data should be launched by the interested agencies, including a continuing record and special appraisals in census years.

Although there has been some discussion by the Water Resources Council on this recommendation, to date, no instructions have been received in the field.

Recommendation 4 - Research on flood plain occupance and urban hydrology should be sponsored by the Department of Housing and Urban Development, Department of Agriculture, and the Geological Survey.

The Department of Housing and Urban Development has initiated research on factors that affect decisions to occupy the flood plain and the problems of urban drainage. Some of this is being done with grants to universities. In this same regard, the Geological Survey, in collaboration with NOAA, is developing the design of improved instruments for measuring water flow in drainage conduits, sewers, and streets in urban areas. In addition, the Department of Agriculture is directing its research program to comparable problems in rural areas.

Recommendation 5 - The Federal Water Resources Council should specify criteria for using flood information and should encourage State agencies to deal with the coordination of flood plain planning and with flood plain regulation.

Under the Water Resources Planning Act, the Council has set up criteria to guide river basin commissions and State planning agencies to consider all reasonable alternatives in water resource development. In addition, States have been encouraged to build staffs and organizations capable of dealing with the coordination of flood plain planning in their areas. Another intent of the recommendation was to require State and/or local regulation of flood plain encroachments as conditions for the construction of Federal and Federally-assisted flood control projects. This is now standard policy for all Federal agencies involved in flood control.

Recommendation 6 - Under the following Federal programs, steps should be taken to assure that State and local planning takes proper and consistent account of flood hazard.

(a) Federal mortgage insurance, loans and assistance to private lenders - This pertains to the policies and practices of the Federal Housing Administration, the Veterans Administration, the Farmers Home Administration, and the Federal Home Loan Bank Board. These agencies involved in insured loans or guarantees are directed to make detailed site investigations as relates to flood hazards before approving the necessary action. This is now required action under Executive Order 11296, dated August 1966. See Figure C-3.

(b) Housing Act, urban planning assistance program Section 701 - This is a support program for comprehensive planning at State and local levels of government. The recommendation was made that this program should be strengthened as relates to water resources and flood problems. HUD has issued guidelines to implement those planning functions more directly related to Federal water planning. The Corps of Engineers has established a Technical Information Service as part of its Flood Plain Management Program to assist local planning agencies. In addition, the Council has contracted with the University of Wisconsin to develop model legislation and ordinances that will be available to local planners.

(c) Federal Aid Highway Act - The Federal Aid Highway Act of 1962 requires a "continuing, comprehensive, transportation planning process in urban areas" where the population exceeds 50,000. Instructional memorandums have been amended to reflect more adequately

Presidential Documents

Title 3—THE PRESIDENT

Executive Order 11296

EVALUATION OF FLOOD HAZARD IN LOCATING FEDERALLY OWNED OR FINANCED BUILDINGS, ROADS, AND OTHER FACILITIES, AND IN DISPOSING OF FEDERAL LANDS AND PROPERTIES

WHEREAS uneconomic uses of the Nation's flood plains are occurring and potential flood losses are increasing despite substantial efforts to control floods; and

WHEREAS national and regional studies of areas and property subject to flooding indicate a further increase in flood damage potential and flood losses, even with continuing investment in flood protection structures; and

WHEREAS the Federal Government has extensive and continuing programs for the construction of buildings, roads, and other facilities and annually disposes of thousands of acres of Federal lands in flood hazard areas, all of which activities significantly influence patterns of commercial, residential, and industrial development; and

WHEREAS the availability of Federal loans and mortgage insurance and land use planning programs are determining factors in the utilization of lands:

NOW, THEREFORE, by virtue of the authority vested in me as President of the United States, it is hereby ordered as follows:

SECTION 1. The heads of the executive agencies shall provide leadership in encouraging a broad and unified effort to prevent uneconomic uses and development of the Nation's flood plains and, in particular, to lessen the risk of flood losses in connection with Federal lands and installations and federally financed or supported improvements. Specifically:

(1) All executive agencies directly responsible for the construction of Federal buildings, structures, roads, or other facilities shall evaluate flood hazards when planning the location of new facilities and, as far as practicable, shall preclude the uneconomic, hazardous, or unnecessary use of flood plains in connection with such facilities. With respect to existing Federally owned properties which have suffered flood damage or which may be subject thereto, the responsible agency head shall require conspicuous delineation of past and probable flood heights so as to assist in creating public awareness of and knowledge about flood hazards. Whenever practical and economically feasible, flood proofing measures shall be applied to existing facilities in order to reduce flood damage potential.

(2) All executive agencies responsible for the administration of Federal grant, loan, or mortgage insurance programs involving the construction of buildings, structures, roads, or other facilities shall evaluate flood hazards in connection with such facilities and, in order to minimize the exposure of facilities to potential flood damage and the need for future Federal expenditures for flood protection and flood disaster relief, shall, as far as practicable, preclude the uneconomic, hazardous, or unnecessary use of flood plains in such connection.

(3) All executive agencies responsible for the disposal of Federal lands or properties shall evaluate flood hazards in connection with lands or properties proposed for disposal to non-Federal public instrumentalities or private interests and, as may be desirable in order to minimize future Federal expenditures for flood protection and flood disaster relief and as far as practicable, shall attach appropriate restrictions with respect to uses of the lands or properties by the purchaser and his successors and may withhold such lands or properties from disposal. In carrying out this paragraph, each executive agency may make appropriate allowance for any estimated loss in sales price resulting from the incorporation of use restrictions in the disposal documents.

(4) All executive agencies responsible for programs which entail land use planning shall take flood hazards into account when evaluating plans and shall encourage land use appropriate to the degree of hazard involved.

SEC. 2. As may be permitted by law, the head of each executive agency shall issue appropriate rules and regulations to govern the carrying out of the provisions of Section 1 of this order by his agency.

SEC. 3. Requests for flood hazard information may be addressed to the Secretary of the Army or, in the case of lands lying in the basin of the Tennessee River, to the Tennessee Valley Authority. The Secretary or the Tennessee Valley Authority shall provide such information as may be available, including requested guidance on flood proofing. The Department of Agriculture, Department of the Interior, Department of Commerce, Department of Housing and Urban Development, and Office of Emergency Planning, and any other executive agency which may have information and data relating to floods shall cooperate with the Secretary of the Army in providing such information and in developing procedures to process information requests.

SEC. 4. Any requests for appropriations for Federal construction of new buildings, structures, roads, or other facilities transmitted to the Bureau of the Budget by an executive agency shall be accompanied by a statement by the head of the agency on the findings of his agency's evaluation and consideration of flood hazards in the development of such requests.

SEC. 5. As used in this order, the term "executive agency" includes any department, establishment, corporation, or other organizational entity of the executive branch of the Government.

SEC. 6. The executive agencies shall proceed immediately to develop such procedures, regulations, and information as are provided for in, or may be necessary to carry out, the provisions of Sections 1, 2, and 3 of this order. In other respects this order shall take effect on January 1, 1967.

LYNDON B. JOHNSON

THE WHITE HOUSE,
August 10, 1966.

[F.R. Doc. 66-8838; Filed, Aug. 10, 1966; 12:14 p.m.]

consideration of flood problems within the context of coordinated transportation and land use planning.

(d) Open Space and recreation area planning - Under the Land and Water Conservation Fund Act of 1965, the Bureau of Outdoor Recreation supports the preparation by States of statewide outdoor recreation plans as a prerequisite to financial assistance for State and local recreation land acquisition and development projects. The Bureau has revised procedures to fully emphasize the opportunities for use of flood plains for the development of recreation areas.

(e) Open Space land acquisition, Title VII, Housing Act of 1961 - Under this act (amended in 1965), Federal grants are made to assist communities in acquiring permanent open space for conservation, recreation, and other purposes. These proposals are required to be linked with a program of comprehensive planning, and the acquisition of open space and its use are required to include consideration of flood hazard. HUD's letter Number OS-17, Open Space Land Program, dated 8 April 1968, describes ranking procedures to establish priorities for available funds if the open spaces meet needs for recreation scenic or conservation areas. Flood plains could fall within these categories.

(f) Greenspan Program - Title VI, Food & Agriculture Act of 1965 - Under this act, the Cropland Adjustment Program (CAP), more popularly called Greenspan, was authorized. This provides adjustment payments to farmers moving land out of surplus crops and into conservation uses for 5-10 year periods. It also provides equivalent help to governmental bodies - local, State and Federal, or a subdivision thereof - desiring to obtain farmland for permanent conversion to open space, public recreation, wildlife habitat, natural beauty, and other uses that control air and water pollution. In 1967, three areas in Maine and one in Connecticut used this program to develop recreation areas. There has been no further activity in this program, since Congress failed to appropriate funds for new business in this program in 1968 or 1969. No need for priorities developed in the program, since funds available satisfied the requests at that time.

(g) Urban Renewal - Urban renewal projects should implement comprehensive community plans and should consistently give explicit consideration to treatment of flood areas and flood hazards. The Corps of Engineers and Urban Renewal Administration have worked out an operating agreement in recognition of this need.

(h) Sewer and Water Facilities (HUD, USDA, HEW, and EDA) - All guides and instructional materials issued in connection with the administration of these programs should require consideration of flood

hazard in the design of projects located in areas that may be flood-prone. HUD originally adopted these guidelines. The other agencies now require these considerations under Executive Order 11296, see Figure C-3.

Recommendation 7 - Actions should be taken by the Office of Emergency Planning (now called Emergency Preparedness), the Small Business Administration, the Treasury Department, and other agencies to support consideration of relocation and flood-proofing as alternatives to repetitive reconstruction.

This applied to relief and rehabilitation to disaster areas where refurbishing obsolete developments have added to the flood damage problem and also invited future relief expenditures. The Treasury Department was asked to revise the tax code so as to provide incentive to relocation of obsolete or hazardously located property and to flood proofing. They were also to consider limiting the number of times flood damage deductions could be claimed for properties located in hazard areas. The Red Cross was asked to take an active role in implementing policies consistent with the above. All the agencies are in the process of implementing these recommendations.

Recommendation 8 - An Executive Order should be issued directing Federal agencies to consider flood hazard in locating new Federal installations and in disposing of Federal land.

The recommendation was implemented by Executive Order 11296 (Figure C-3), referred to previously. It was signed by the President on 10 August 1966, to become effective on 1 January 1967. The order was issued on the same date that H. D. 465 was transmitted to the Congress. It should be noted that prior to this time, the Federal Government often found itself providing flood control in one area and subsidizing unwise decisions in the flood plain in another area. The Executive Order minimizes the probability of this situation occurring in the future.

Recommendation 9 - Programs to collect, prepare, and disseminate information and to provide limited assistance and advice on alternative methods of reducing flood losses, including land regulation and flood-proofing, should be undertaken by the Corps of Engineers in close coordination with the Department of Housing and Urban Development and the Department of Agriculture.

As a result of this recommendation, the Corps of Engineers has established a Flood Plain Management Services program with personnel in each Division and District office assigned to this function. The New England Division, Corps of Engineers office in Waltham, Massachusetts,

is responsible for the administration of this program in the six New England States (excluding the Hoosic River drainage in western Massachusetts and the Lake Champlain drainage in Vermont). These other areas come under the jurisdiction of the North Atlantic Division and New York District offices in New York City.

In addition to the Flood Plain Information Reports discussed under Recommendation 1, the program provides for Technical Information Services to Federal and non-Federal agencies in evaluating and using flood data in making individual decisions concerning flood hazards. This is provided to permit wise decisions concerning location of public buildings, subdivisions, and other land uses. This technical assistance also includes the interpretation of flood data and guidance in the preparation of flood plain regulations.

Pamphlets on "Guidelines for Reducing Flood Damages" and "Introduction to Flood Proofing" have been published by the Corps of Engineers in cooperation with TVA and the University of Chicago. Copies have been made available to interested agencies at all levels of Government. Pamphlets highlighting the flood problems for the Connecticut and Thames Rivers were prepared for the respective Flood Control Commissions. Flood Plain Management Services provided by the Corps of Engineers are described in Exhibit C-2.

Recommendation 10 - An improved system for flood forecasting should be developed by the Environmental Science Services Administration as part of a disaster warning service.

Since House Document 465 was written, reorganization within the Department of Commerce has resulted in the above noted Environmental Science Services Administration's being expanded and becoming the National Oceanic and Atmospheric Administration, (NOAA). Also, the Weather Bureau is now the National Weather Service, (NWS).

River and flood forecasting in New England is the responsibility of the NWS River Forecast Center (RFC) in Hartford, Connecticut. Although this service in New England has been termed "adequate", considerable improvement of the service is required to provide water management organizations - both public and private - with prediction of sufficient frequency, detail and accuracy to enable optimization of water resources management. Any significant improvement in the forecasting service depends upon the availability of near real-time precipitation and river stage observations and adequate computer capability at the RFC. In addition, expanded hours of operation of the RFC would be required for quick response to weather events. Present technology

with regard to instruments, communications, and computer science are more than adequate for present and foreseeable requirements. Modern forecasting techniques, i. e., continuous streamflow prediction models, are also available.

Recommendation 11 - A study of the feasibility of flood insurance under various conditions should be carried forward by the Department of Housing and Urban Development.

Feasibility studies have been carried out, and favorable findings resulted in enactment of the National Flood Insurance Act (P. L. 90-448) by Congress in August 1968. (A portion of the Act, concerning the coordination of flood insurance with land management programs in flood plains, is reproduced as Figure C-4. Essentially, the program authorizes the Secretary of Housing and Urban Development to subsidize insurers who write policies covering flood damage to improved property. One condition on the application of this program to a particular area is that satisfactory controls must be established to restrict use of the undeveloped flood-proof lands in that area. Of the 28 towns eligible for flood insurance in Massachusetts, 3 are located in the Charles River watershed.

Recommendation 12 - Survey authorization procedure and instructions should be broadened in concept.

Study of alternatives - executive authority should be exercised to direct the agencies conducting surveys to present in survey reports alternative solutions, as well as recommendations for decision by the Congress. This is now standard procedure for all survey studies.

Recommendation 13 - A modification in the cost sharing requirement for Federally-assisted projects.

This is intended to eliminate many of the inequities existing within agency programs and among different agencies. The precise formula is a matter of political adjustment and equity rather than a problem of technical judgment.

Recommendation 14 - Flood project benefits should be reported in the future so as to distinguish protection of existing improvements from development of new property.

This is current policy of Federal agencies involved in determining flood project benefits.

CHAPTER III—COORDINATION OF FLOOD INSURANCE WITH LAND-MANAGEMENT PROGRAMS IN FLOOD- PRONE AREAS

IDENTIFICATION OF FLOOD-PRONE AREAS

Contract
authority.

SEC. 1360. The Secretary is authorized to consult with, receive information from, and enter into any agreements or other arrangements with the Secretaries of the Army, the Interior, Agriculture, and Commerce, the Tennessee Valley Authority, and the heads of other Federal departments or agencies, on a reimbursement basis, or with the head of any State or local agency, or enter into contracts with any persons or private firms, in order that he may—

Publication
of information.

(1) identify and publish information with respect to all flood plain areas, including coastal areas located in the United States, which have special flood hazards, within five years following the date of the enactment of this Act, and

Flood-risk
zones.

(2) establish flood-risk zones in all such areas, and make estimates with respect to the rates of probable flood-caused loss for the various flood-risk zones for each of these areas, within fifteen years following such date.

CRITERIA FOR LAND MANAGEMENT AND USE

SEC. 1361. (a) The Secretary is authorized to carry out studies and investigations, utilizing to the maximum extent practicable the existing facilities and services of other Federal departments or agencies, and State and local governmental agencies, and any other organizations, with respect to the adequacy of State and local measures in flood-prone areas as to land management and use, flood control, flood zoning, and flood damage prevention, and may enter into any contracts, agreements, or other appropriate arrangements to carry out such authority.

(b) Such studies and investigations shall include, but not be limited to, laws, regulations, or ordinances relating to encroachments and obstructions on stream channels and floodways, the orderly development and use of flood plains of rivers or streams, floodway encroachment lines, and flood plain zoning, building codes, building permits, and subdivision or other building restrictions.

(c) On the basis of such studies and investigations, and such other information as he deems necessary, the Secretary shall from time to time develop comprehensive criteria designed to encourage, where necessary, the adoption of permanent State and local measures which, to the maximum extent feasible, will—

(1) constrict the development of land which is exposed to flood damage where appropriate,

(2) guide the development of proposed construction away from locations which are threatened by flood hazards,

(3) assist in reducing damage caused by floods, and

(4) otherwise improve the long-range land management and use of flood-prone areas,

and he shall work closely with and provide any necessary technical assistance to State, interstate, and local governmental agencies, to encourage the application of such criteria and the adoption and enforcement of such measures.

PURCHASE OF CERTAIN INSURED PROPERTIES

SEC. 1362. The Secretary may, when he determines that the public interest would be served thereby, enter into negotiations with any owner of real property or interest therein which—

(1) was located in any flood-risk area, as determined by the Secretary,

(2) was covered by flood insurance under the flood insurance program authorized under this title, and

(3) was damaged substantially beyond repair by flood while so covered,

and may purchase such property or interests therein, for subsequent transfer, by sale, lease, donation, or otherwise, to any State or local agency which enters into an agreement with the Secretary that such property shall, for a period not less than forty years following transfer, be used for only such purposes as the Secretary may, by regulation, determine to be consistent with sound land management and use in such area.

Recommendation 15 - Authority should be given by the Congress to include land acquisition as a part of flood control plans.

The executive branch should submit legislation which would establish clear authority and principles for acquiring and disposing of flood plain lands when such action is found to be part of a practical solution for a feasible flood project. This would make land acquisition available as an additional measure for flood plain management and could be done by providing additional assistance under existing open space land programs. Where States or local public bodies are unable or unwilling to acquire land in accordance with a community program authority could be made available to Federal agencies to acquire land that is essential to implement the plan. To date, there has been no legislative action on this.

Recommendation 16 - Loan authority for local contributions to flood control projects should be broadened by the Congress.

Present authority limits loans to local organizations under Farmers Home Administration for P. L. 534 and 566 projects, local projects in TVA, and in depressed areas through the Department of Commerce. This recommendation would extend the authority to cover all cases of demonstrable financial need. No action has been taken on this recommendation to date.

4. SUMMARY OF MAJOR FEDERAL ASSISTANCE PROGRAMS

a. Flood Plain Delineation

(1) The USGS is preparing flood plain maps from available data to provide a general appraisal of flood-prone areas.

(2) The U. S. Army Corps of Engineers has published a number of reports on flood protection studies for urban areas. Unpublished flood information is also available.

b. Federal Assistance Programs

(1) Comprehensive Planning Assistance(HUD): A support program for up to 75 percent of costs of comprehensive planning at State, regional, metropolitan, and local levels of government.

(2) Open-space Land Acquisition (HUD).

(3) Land and Water Conservation Fund (BOR): Federal grants of 50 percent of land acquisition costs for open space (HUD) or Outdoor Recreation (BOR) areas.

(4) Pittman-Robertson Acts for Wildlife Restoration (BSFW).

(5) Dingell-Johnson Act for Sport Fish Restoration (BSFW): Federal reimbursement to States of 75 percent of costs on sport fish and wildlife projects.

(6) Greenspan Program (USDA): Grants up to 50 percent of crop land acquisition costs for preservation of open spaces or natural beauty, development of recreational land wildlife services or prevention of air and water pollution.

(7) Flood Insurance (HUD): A new program for flood insurance in flood-prone areas.

5. WHAT CAN BE DONE

a. General

The town or city is, under existing laws in New England, the public authority most advantageously situated to act directly to secure the wise use of flood plains. Towns can zone flood-prone lands, controlling development of such areas for relatively little public expenditure. Towns can also acquire lands which are frequently flooded and which have important public values as recreation sites, natural areas, or as areas needed for the exercise of other municipal functions. States can play a complementary role, regulating channel encroachments and acquiring lands for public purposes, while the Federal government can plan a supporting role.

b. Planning and Zoning

A community should first have a plan for its development and land use, and a zoning code to implement the plan. Establishment of a town conservation commission is another useful step. The conservation commission can provide an official forum for interested citizens to discuss their town's natural resources, including its flood plains. Assistance, both technical and financial, may be secured from State Planning and Natural Resources agencies and, for comprehensive planning, from the U. S. Department of Housing and Urban Development.

c. Delineation of Flood Hazard Areas

Before a community can adopt zoning restrictions for its flood plain lands, it must map the areas subject to various frequencies of flooding. Assistance from several Federal agencies is available for this complex work. As discussed in Recommendation 1, the Corps of Engineers, the U. S. Geological Survey, and the Soil Conservation Service all have programs which can provide the detailed flood risk maps and profiles. The USGS is also preparing the less detailed "Area of Occasional Flooding"

NEED FOR FLOOD PLAIN PLANNING STUDIES



A large investment.....



.....It should be a wise one.

maps. In addition, the wealth of data developed by the Corps of Engineers and SCS in their flood control studies can be used to develop preliminary mapping to initiate planning. The U. S. Coast and Geodetic Survey may also be able to provide assistance on coastal mapping. This type of data is needed in the Flood Insurance Program by HUD. The Flood Insurance Act also provides for additional Federal assistance in a delineation program. The coordination and acceleration of these programs are currently being held in check by budgetary limitations. A community may have to wait several years for flood hazard information report. A quicker, although costlier alternative is to hire a consulting firm to map the flood plains and to draft appropriate legislation for the town's consideration. The names of consulting firms specializing in flood plain studies can be obtained from State planning offices.

d. Acquisition Assistance

Communities may, of course, acquire simple fee title to flood prone lands. Generally, communities will not acquire lands specifically to control flood losses unless the need is so compelling as to justify acquisition so that zoning would be a more appropriate action. But flood prone lands are often of high value for open space, scenic values, fish and wildlife habitat, or outdoor recreation, as well as for natural capacity to store flood waters or recharge underground aquifers. In such cases, both communities and States may - and frequently do - acquire such lands for one or more of these purposes - with the incidental benefit of preventing unwise development encroaching on flood plains.

Under the Land and Water Conservation Fund administered by the Bureau of Outdoor Recreation, U. S. Department of the Interior, and the Open Space Program administered by the Department of Housing and Urban Development, 50 percent Federal Grants may be available to assist in acquisition of flood plain lands of high value for outdoor recreation and open space (including conservation purposes). Supplementary State assistance may also be available to assist local communities in acquiring park and outdoor recreation lands, in addition to the Federal contribution. State fish and game departments may utilize funds (75 percent Federal) under the Pittman-Robertson and Dingell-Johnson programs to acquire and manage flood plain lands of high fishery and wildlife value. As indicated in Recommendation 6, HUD, Agriculture, and Interior (BOR) have in the recent years established policies to give flood plains and wetlands due consideration in establishing their program priorities.

e. Direct Federal Actions

Federal participation in flood plain management is limited to technical assistance to the State or local government, which is expected to establish some form of zoning. It is recognized that zoning in many cases is a temporary measure. As community expansions take place, land values may change and economic pressures will demand structural measures to permit changing land uses in the flood plain. If the structures are to be built as Federal projects under Comprehensive River Basin Planning, there appears to be a need for a greater Federal interest in zoning as a coordinated non-structural measure. This concept combined with Federal acquisition of flood plains (Recommendation 15) should be the subject of further study, since new legislation will be required.

f. State Actions

The Corps of Engineers, Flood Plain Management Program includes the function of coordinating the results of the Federal assistance program on flood plain uses. There does not appear to be any comparable coordination at the State level of government. In most cases, the general responsibility for zoning is in one agency, while flood plain zoning may or may not be in a single department such as a water resources agency. This also applies, as noted in the previous paragraph, to coordination of the open space programs. To be truly effective, a single State office should have as one of its major responsibilities, Flood Plain Management. A compromise solution would be the creation of a special board, council, or committee with the interested State agencies as members. This would also simplify the liaison with the local communities.

It is also possible that current reorganization planning being conducted will centralize non-structural flood management in a single agency within the Cabinet Office of Environmental Affairs.

The State of Connecticut is the only New England State that has its own flood plain delineation program, which is a necessary part of its channel encroachment law. It is recognized that these are engineering studies, and expensive. However, as other States developed State-wide programs, their budgets should make provisions for developing flood plain delineations as a supplement to the Federal programs in achieving the coverage required for sound planning decisions.

Another immediate action that can be taken by the States to insure wide flood plain use could be by executive order, as issued by the Governor of Maine in March 1968. This action, similar to the Federal executive order, would insure that State funds would not be used to subsidize unwise decisions in those situations where Federal funds were not involved,

In a similar vein, legislation has been filed in Massachusetts which would require an environmental statement procedure relative to State-funded programs which would be similar in purpose to the National Environmental Policy Act.

g. Other Future Considerations

Flood forecasting and collecting flood damage data are necessary to the wise use of flood plains. Unfortunately, these two items are frequently overlooked or given only token consideration when flood plain problems are being considered. Similarly, climatological information which should be of considerable value to planners is usually skimpy. Means, extremes, and frequencies of weather elements can be provided for any section of the country and in as much detail as required. Since weather affects all activities within a study area, climatological probabilities should be one of the planner's most valuable tools.

Although these needs are recognized here, they have not been sufficiently emphasized to find support in the budget process. Greater emphasis should be placed upon these requirements so that new policies and procedures will insure their availability.

H. Conclusion

Land requirements of an expanding economy are reflected in the development and use of the flood plains. Because of the apparent economic advantages of flood plain lands in urban areas, such action will likely intensify in the future. A flood plain management program can temper the rate of such development. A blending of the control of excess flows and the managed use and development of flood plains can be expected, generally, to provide an optimum program to reduce flood losses. There are many tools available under present programs to achieve the managed use. What is needed is a sincere concerted effort on the part of all agencies to seek this common goal. In New England, a relatively small area of many political subdivisions, coordination can become complex. However, the common goal of flood damage prevention should be incentive to achieve the necessary coordination between Federal, State and municipal agencies.

NOTES:

ELEVATIONS REFER TO MEAN SEA LEVEL DATUM
CONTOUR INTERVAL EQUALS TEN FEET
TOPOGRAPHY IS BASED ON U.S.G.S. MAPS

LEGEND

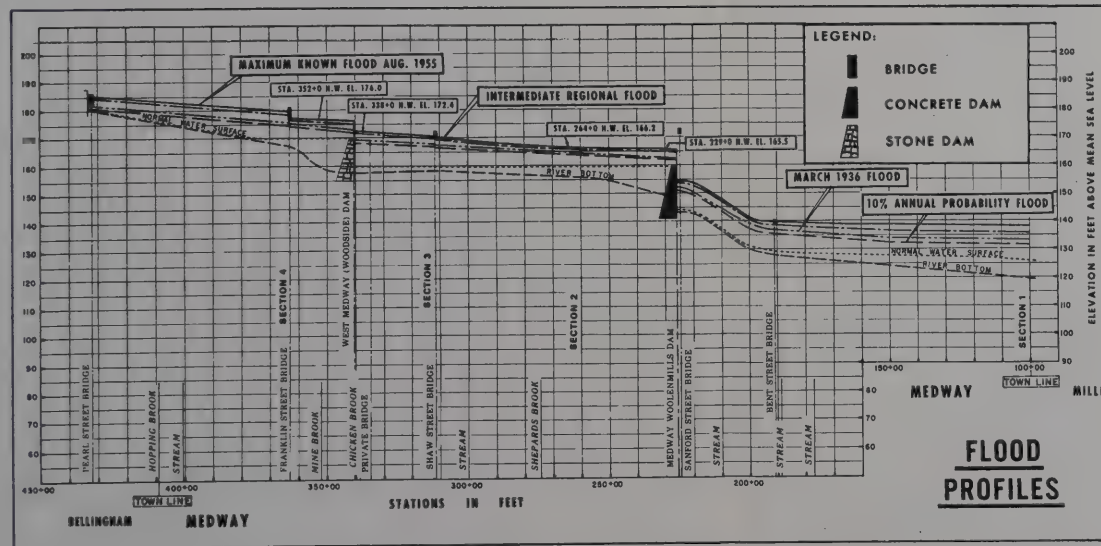
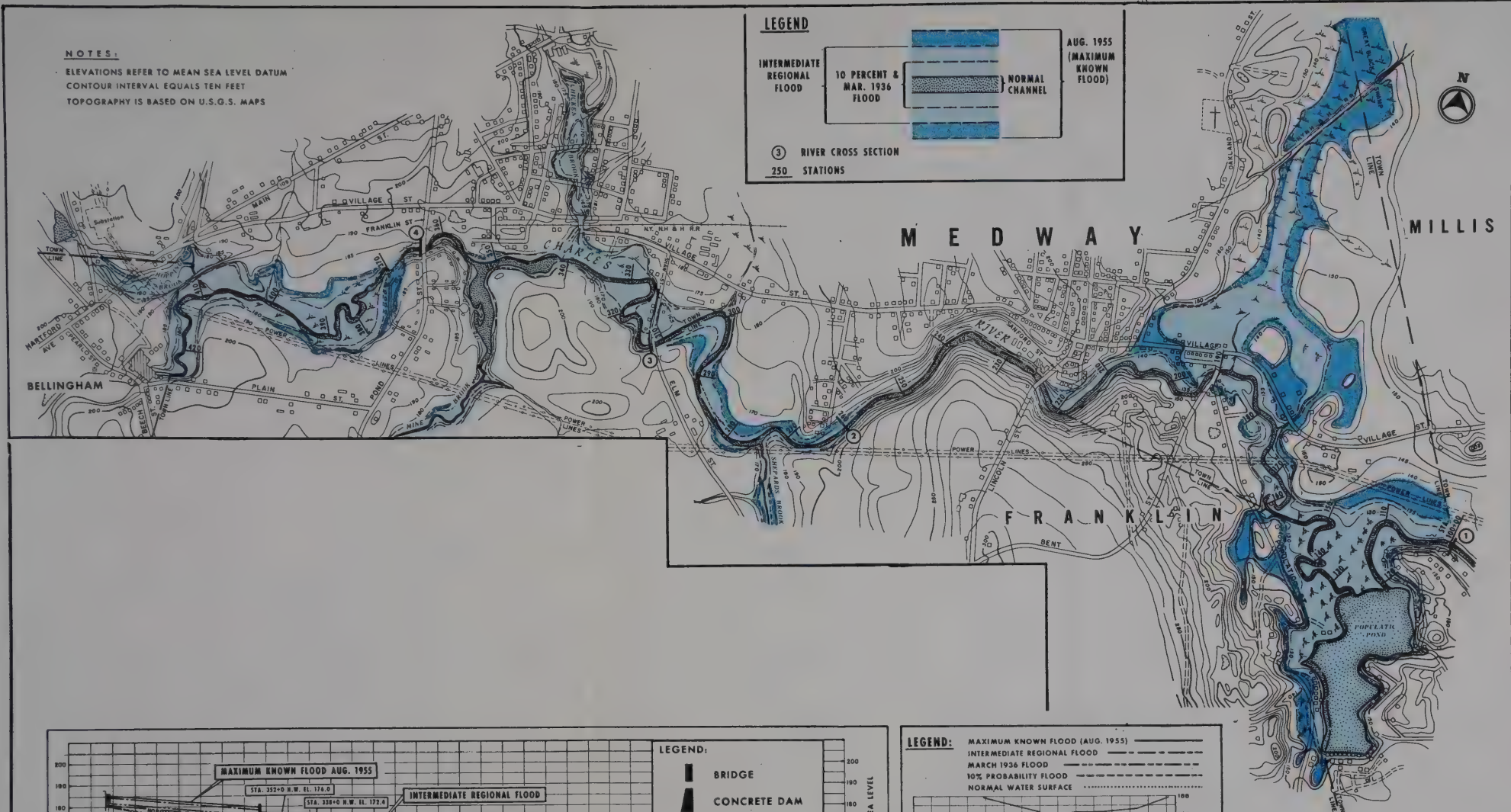
INTERMEDIATE
REGIONAL
FLOOD

10 PERCENT &
MAR. 1936
FLOOD

NORMAL
CHANNEL

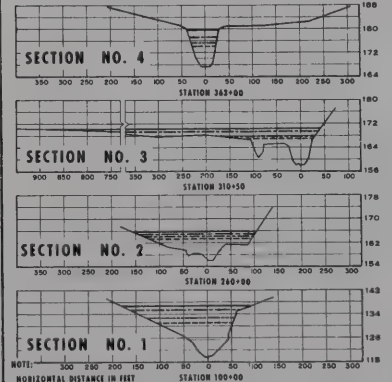
AUG. 1955
(MAXIMUM
KNOWN
FLOOD)

③ RIVER CROSS SECTION
250 STATIONS



LEGEND:

MAXIMUM KNOWN FLOOD (AUG. 1955)
INTERMEDIATE REGIONAL FLOOD
MARCH 1936 FLOOD
10% PROBABILITY FLOOD
NORMAL WATER SURFACE



NOTE: HORIZONTAL DISTANCE IN FEET
SECTIONS TAKEN LOOKING DOWNSTREAM

RIVER CROSS SECTIONS

SCALE IN FEET
500 0 500 1000 1500

FLOOD PLAIN INFORMATION
CHARLES RIVER
MEDWAY, MASS.

FLOOD PLAINS

AUGUST 1967

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.

EXHIBIT C-2

FLOOD PLAIN MANAGEMENT SERVICES

AS PROVIDED BY THE CORPS OF ENGINEERS

Section 206 of the Flood Control Act approved 14 July 1960 (P. L. 86-645), as amended, authorizes the Secretary of the Army, through the Chief of Engineers, to compile and disseminate information on floods, flood damage potentials, and general criteria for guidance of Federal and non-Federal interests and agencies in the use of flood plain areas. Under this authorization, the Corps of Engineers carries out its Flood Plain Management Services program.

The purpose of the authorization is to make information, guidance, and advice on flood hazards available to Federal, State, and local governmental agencies which will permit them to proceed with such planning, engineering studies, construction, and other action as may be necessary for wise use of flood plains. Application of such information and guidance by these agencies is intended to help in planning and regulating the use of flood plain areas to reduce flood hazards and flood damage potential which otherwise could arise from unwise flood plain development.

The Flood Plain Management Services program includes preparation of flood plain information reports; provision of technical services and guidance in the interpretation of basic data, preparation of flood plain regulations, and application of concepts such as structural flood proofing of new and existing buildings; preparation of guides and pamphlets; conduct of related research; and long-range comprehensive flood damage reduction planning.

1. Flood Plain Information Reports

Flood Plain information reports are prepared upon request of State and local agencies to delineate flood problems in communities throughout the country. The Corps of Engineers has gathered much flood plain information during the conduct of its previously authorized responsibilities for flood control. Such information is assembled and organized under this program. When necessary, additional topographic surveys and hydrologic studies are undertaken. A typical report includes maps or mosaics, profiles, charts, tables, and a narrative describing the extent, depth, probability and duration of flooding by floods of the past and those that may be expected in the future.

EXHIBIT C-2 (Cont'd)

It is the responsibility of the State and local government agencies to publicize the information and put it to use through planning groups, zoning boards, private citizens, engineering and planning firms, real estate and industrial developers, and others to whom it would be useful. State and local agencies also are expected to cooperate in providing appropriate assistance, advice, and guidance to ameliorate the flood hazard.

2. Technical Services and Guidance

Experience to date shows encouraging results from completed reports. State and local governmental agencies and private interests have used them in various ways, such as adoption of flood plain regulations, setting size of openings for bridges, and location of public and private buildings. The expanding technical services program is expected to greatly increase the use and benefits of the basic data presented in the flood plain information reports. The technical services function includes (a) help in interpretation and evaluation of basic data and guidance in preparation of flood plain regulations; (b) advice in use of basic data in actions regarding possible alternative developments in flood prone areas; and (c) guidance on structural and nonstructural measures which might be employed to reduce flood damage potentials or flood losses.

Starting in 1967, this program has included assistance and guidance not only to State and local agencies but to Federal agencies as well, in accordance with requirements of Executive Order 11296. This Order is concerned with site location of innumerable Federal improvements, disposal of Federal properties in flood hazard areas, and proper consideration of flood hazard in all Federal grant, loan mortgage insurance, and land use planning programs.

3. Guides, Pamphlets, and Research

This aspect of the program includes studies to improve methods and procedures for flood damage prevention and abatement, in addition to preparation of guides and pamphlets pertaining to flood proofing, flood plain regulations, flood plain occupancy, economics of flood plain regulations, and other related approaches to flood damage prevention. These activities are being coordinated with related programs of other Federal and State agencies. Guides and pamphlets are distributed for use by State and local governments, private citizens, and Federal agencies in planning and taking action to reduce their flood damages or damage potential.

EXHIBIT C-2 (Cont'd)

4. Comprehensive Flood Damage Prevention Planning

Comprehensive flood damage prevention planning, at all appropriate governmental levels, is the composite and ultimate objective of the Flood Plain Management Services Program. It is not a separable activity, but takes place through preparation and dissemination of flood plain information reports, through provision of technical advice and other forms of assistance to persons and governmental entities concerned with flood hazard problems, and through continuing research on means for dealing more effectively with flood problems. The purpose of these activities, taken together, is to encourage and guide the best and safest use possible of flood plain lands for the benefit of the national economy and welfare. The program provides a highly desirable and useful tool in rounding out the national effort in treating flood problems and provides a direct complement to other Corps' flood control efforts.

WATER RESOURCES INVESTIGATION

CHARLES RIVER STUDY

APPENDIX D

HYDROLOGY AND HYDRAULICS

PREPARED BY

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASSACHUSETTS

DECEMBER 1971

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APPENDIX D

HYDROLOGY AND HYDRAULICS

1. INTRODUCTION

This appendix presents the hydrology and hydraulics for the subject Charles River Study. Included are sections on general description, climatology, streamflow, and hydrologic studies. Studies reported in this appendix pertain primarily to the upper watershed. Detailed studies of the lower Charles River Basin were reported in "Interim Report on Charles River for Flood Control and Navigation, Lower Charles River, Massachusetts".

2. CHARLES RIVER WATERSHED

The Charles River watershed, located in eastern Massachusetts is surrounded by the drainage areas of the Mystic, Merrimack, Blackstone, Taunton, and Neponset Rivers. It has a total drainage area of 307 square miles which includes an important and highly developed portion of Metropolitan Boston and less developed but rapidly growing suburban and rural areas.

The watershed, shown on Plate D-1, is hourglass in shape with a length in a southwest-northeast direction of 31 miles and widths of 15, 5, and 15 miles in a northwest-southeast direction. Elevations vary from 586 feet above mean sea level (msl), along the southwesterly rim of the watershed in Hopkinton, to about 10 feet msl, along the lower 8-1/2 miles of the Charles River.

Within the drainage area there are 33 lakes and ponds having a total surface area of 2,530 acres, not including ponded areas along the river itself. The combination of moderate slopes, sandy pervious soil, extensive swamplands, dams and lake storage, all contribute to make the upstream section of the river unusually slow in responding to heavy rains. Plate D-2 presents a graphic illustration of the cumulative drainage areas of the entire Charles River, from its source, upstream of Echo Lake, to its mouth at Boston Inner Harbor.

3. CHARLES RIVER

The Charles River rises in the town of Hopkinton, approximately 25 miles southwest of the city of Boston. The river follows a generally

northeasterly course, meandering through extensive swamplands and passing through many heavily built-up areas until it reaches the Charles River Basin, a term commonly used for that portion of the river extending from Watertown to tidewater at the existing Charles River dam.

The river is nearly 80 miles long with a fall from its source to the Charles River Basin of approximately 350 feet. In the lower 33 miles, the drop is 98 feet. There are approximately 22 dams located on the river, some of which are still used for impounding mill process water. A profile of the entire Charles River is shown on plate D-3.

4. UPPER CHARLES RIVER WATERSHED

a. General

The upper Charles River watershed is assumed, for hydrologic purposes, to extend from the headwaters at Echo Lake in Hopkinton for approximately 66 miles to the Moody Street dam in Waltham. This subdivision of the total watershed covers an area of 249 square miles. A description of the lower portion of the watershed is included in the Lower Charles River Interim Report dated May 1968. The area at the western and northern parts of the upper watershed is moderately hilly land while the eastern and southern parts are characterized by rolling topography with extensive swampy areas. From Echo Lake in Hopkinton to the Medway dam, the main river falls approximately 100 feet in a distance of 18 miles, an average slope of 5.5 feet per mile. From the Medway dam to the South Natick dam, a distance of 20 miles, the Charles River drops about 40 feet, an average slope of about 2 feet per mile. This reach of river contains extensive natural valley storage which tends to modify floodflows. From the South Natick dam to the Moody Street dam in Waltham, the river falls approximately 75 feet in a distance of 30 miles.

b. Major Tributaries

The Charles River, in its general northeasterly course to the ocean, is fed by a number of rivers and streams. Pertinent data on the principal tributaries are contained in table D-1. The 7 largest tributaries with areas greater than 10 square miles, having an aggregate area equal to 50 percent of the upper watershed, are briefly described as follows:

(1) Hopping Brook

This tributary has its source in the town of Holliston from which it flows in a general southerly direction to its mouth at the Charles

River in the town of Bellingham. The area through which it flows is moderately hilly and drops about 120 feet in its 8 mile length. It has a drainage area of 11.5 square miles.

(2) Mine Brook

The headwaters of this tributary are in the southwestern part of the town of Franklin. From its source this brook flows in a northeasterly direction for about 8 miles where it turns westerly to Unionville. It then travels in a northerly direction for about 4 miles to its confluence with the Charles River at the northerly edge of Franklin. Mine Brook has a drainage area of 15.7 square miles and includes a number of large ponds along its length. It has a fall of about 160 feet in its total length of 12 miles.

(3) Mill River

The Mill River originates in the town of Wrentham and flows in a general northerly direction for about 7 miles to its confluence with the Charles River in the town of Norfolk. Two relatively large bodies of water, Lake Pearl and Lake Archer, are located in the upper reaches of this river. It has an area of 16.3 square miles and a fall of approximately 150 feet.

(4) Stop River

This river, with a drainage area of 17.1 square miles, originates in the town of Norfolk. It follows a winding course in a general northerly direction for about 7 miles to its confluence with the Charles River in the town of Medfield. It has a fall of 100 feet and is characterized by a wide swampy area at its mouth.

(5) Bogastow Brook

Bogastow Brook, the largest tributary of the Charles River, has a drainage area of 25.5 square miles. From its source in the town of Holliston, this brook flows generally southeasterly for about 9 miles where it turns northerly at the Great Black Swamp. It then travels in a northeasterly direction for about 3 miles to its confluence with the Charles River in the town of Millis. The watershed contains a number of large ponds and includes Lake Winthrop located south of the town of Holliston. The extensive swampland in the lower portion of Bogastow Brook serves as a large storage area during the time of severe storms.

TABLE D-1

PERTINENT DATA
CHARLES RIVER TRIBUTARIES

<u>Tributary</u>	<u>Drainage Area (sq. mi.)</u>	<u>Junction With Main River</u>	
		<u>Location</u>	<u>At River Mile *</u>
Hopping Brook	11.5	Medway	64.3
Mine Brook	15.7	Franklin	63.2
Chicken Brook	7.0	Medway	62.9
Shepards Brook	5.0	Franklin	61.8
Mill River	16.3	Norfolk	57.6
Stop Brook	17.1	Medfield	51.8
Bogastow Brook	25.5	Millis	48.4
Wakan & Fuller Brooks	16.1	Wellesley	39.4
Trout Brook	4.6	Dover	37.2
Stony Brook	23.6	Waltham	14.7
Beaver Brook	11.2	Waltham	12.2
Muddy River**	21.1	Boston	2.8

*Mile 0 is assumed as intersection of centerlines of Charles River and Boston Inner Harbor Channel

**Includes 13.9 square mile drainage area of Stony Brook (Boston)

(6) Waban and Fuller Brooks.

Waban and Fuller Brooks originate in the towns of Weston and Wellesley. Nonesuch Pond, Morses Pond and Lake Waban are principle bodies of water located within the Waban Brook watershed. It has a total fall of about 90 feet in its 6 mile length. Fuller Brook joins Waban Brook in Wellesley about 600 feet above the confluence with the Charles River. Fuller Brook has a total length of approximately 2 miles and a fall of 20 feet. The combined drainage areas of Waban and Fuller Brooks is 16.1 square miles.

(7) Stony Brook

The second largest of the Charles River tributaries, Stony Brook, has its source in Sandy Pond, Lincoln. It flows in a general southeasterly direction for a distance of approximately 7 miles to its confluence with the Charles River in Waltham. Hobbs Brook and Stony Brook Reservoirs, located within the watershed, are reserved exclusively for water supply for the city of Cambridge. Stony Brook has an area of 23.6 square miles and a fall of about 170 feet.

5. CLIMATOLOGY

a. General

The climate of the Charles River watershed is characterized by variable weather, with frequent but usually short periods of precipitation. The area is exposed to intense rainfall due to coastal storms of tropical origin that travel up the Atlantic seaboard or storms of extratropical nature, often called "northeasters". The watershed also lies in the path of the "prevailing westerlies" and with air masses moving predominantly from the interior of the country. This west to southwest airflow brings the hot dry weather which is responsible for occasional summer droughts.

b. Temperature

The average annual temperature of the Charles River watershed is about 49° Fahrenheit, with a range from about 50° near the coast to about 48° at the higher elevations. Average monthly temperatures vary widely throughout the year from between 70° and 72° in July to between 25° and 28° in January. Means in Boston are slightly higher due to urbanization. Temperature extremes range from occasional highs slightly in excess of 100° to infrequent lows below minus 20° Fahrenheit. The mean monthly and yearly temperatures at several National Weather Service stations are shown in tables D-2 and D-3

TABLE D-2

MONTHLY TEMPERATURE AND PRECIPITATION
FRAMINGHAM, MASSACHUSETTS

<u>Month</u>	<u>Temperature</u> <u>83 Years of Record</u>			<u>Precipitation</u> <u>92 Years of Record</u>		
	<u>Mean</u>	<u>Maximum</u>	<u>Minimum</u>	<u>Mean</u>	<u>Maximum</u>	<u>Minimum</u>
January	26.6	72	-24	3.94	9.67	0.75
February	26.8	66	-21	3.75	8.82	0.26
March	36.2	85	-3	4.16	9.61	0.04
April	47.2	93	10	3.66	8.78	0.85
May	58.3	96	25	3.23	7.01	0.72
June	67.2	100	35	3.27	9.33	0.38
July	72.3	102	42	3.48	11.80	0.73
August	69.8	104	34	3.65	15.69	0.54
September	62.9	95	27	3.56	10.65	0.18
October	52.3	91	16	3.32	10.26	0.10
November	41.0	83	6	3.97	7.97	0.89
December	30.0	71	-16	3.84	10.87	0.92
ANNUAL	49.2	104	-24	43.83	59.94	28.96

TABLE D-3

MONTHLY TEMPERATURE AND PRECIPITATION
WALPOLE, MASSACHUSETTS

<u>Month</u>	<u>Temperature</u> <u>19 Years of Record</u>			<u>Precipitation</u> <u>19 Years of Record</u>		
	<u>Mean</u>	<u>Maximum</u>	<u>Minimum</u>	<u>Mean</u>	<u>Maximum</u>	<u>Minimum</u>
January	27.4	69	-19	4.03	9.79	0.76
February	28.6	70	-19	3.76	4.97	1.84
March	35.4	77	-13	4.07	8.71	1.60
April	46.0	90	10	3.87	6.75	0.94
May	55.8	92	22	3.39	8.11	0.61
June	65.2	95	33	2.53	6.40	0.08
July	70.2	100	39	2.91	7.47	0.21
August	68.0	98	32	3.90	20.48	0.99
September	60.6	100	26	3.94	8.88	0.71
October	51.4	88	15	3.62	9.86	1.63
November	41.6	82	7	4.61	7.90	2.22
December	30.1	68	-11	3.76	6.45	0.72
ANNUAL	48.4	100	-19	44.39	57.22	27.96

c. Precipitation

The average annual precipitation over the entire watershed is approximately 44 inches distributed rather uniformly throughout the year. At any one location, the range of average monthly precipitation is about 1 to 2 inches. At Framingham where the National Weather Service has maintained records for 92 years, nearly 60 inches of precipitation fell in 1888. At the same location, less than 29 inches were recorded in 1965. Tables D-2 and D-3 summarize the precipitation records at Walpole and Framingham.

d. Snowfall

The annual snowfall over the watershed varies from about 45 inches near the coast to about 55 inches at the higher elevations of the central and southern portions. The average monthly and annual snowfall at Framingham and Milford is shown in table D-4. Snow cover reaches a maximum depth in an average year by mid-February except a little later at the highest elevations, where the early spring water content may range from 3 to 6 inches.

e. Storms

The rapidly moving cyclonic storms or "lows" that move into New England from the west or southwest produce frequent periods of unsettled, but seldom extremely severe weather. The region is frequently exposed to coastal storms, some of tropical origin, that travel up the Atlantic coast and move over or within striking distance of the Charles River watershed. The most severe storms have been of tropical origin which occur during late summer and early autumn.

Five recent flood producing storms in the Charles River watershed occurred in March 1936, July 1938, September 1954, August 1955, and March 1968. The hurricane "Diane" storms of August 1955 produced floods throughout much of southern New England. The accompanying rains fell on ground previously saturated by rainfall from hurricane "Connie" which occurred one week earlier. Rainfall amounts, for the period from the 17th to the 20th, ranged from 10 to 15 inches over the watershed.

6. STREAMFLOW

a. Discharge Records

The U.S. Geological Survey maintains and publishes records of four stream gaging stations in the Charles River watershed. A summary

TABLE D-4

MEAN MONTHLY SNOWFALL
(Depths in Inches)

<u>Framingham, Massachusetts</u> Elevation 172 feet msl 37 Years of Record		<u>Milford, Massachusetts</u> Elevation 280 feet msl 31 Years of Record	
<u>Month</u>	<u>Snowfall</u>	<u>Month</u>	<u>Snowfall</u>
January	13.6	January	12.1
February	13.7	February	12.9
March	9.9	March	10.2
April	1.7	April	1.4
May	T	May	T
June	0	June	0
July	0	July	0
August	0	August	0
September	0	September	0
October	T	October	T
November	2.6	November	3.0
December	9.3	December	9.2
ANNUAL	50.8	ANNUAL	48.8

of stream flow records at the gaging stations are shown in table D-5. Mother Brook at Dedham, Massachusetts is a diversion from the Charles to the Neponset River. The gage on this stream measures the amount of diversion.

b. Runoff

The average annual runoff of the Charles River for the period of record through 1969 is 292 cfs at Charles River Village, Massachusetts.

A summary of the maximum, minimum and mean monthly runoff is given in table D-6.

7. FLOODS

a. General

Outstanding floods in the Charles River watershed may be expected to occur during any season of the year. Early spring rains combined with melting snow resulted in the floods of March 1936 and March 1968. Heavy rains during summer months caused the floods of July 1938 and August 1955. Due to the large amount of natural storage in the watershed, volume of rainfall rather than intensity is most critical in determining flood magnitude.

b. Historic Floods

The flood history of the Charles River prior to the turn of the century is meager. From all available information the greatest flood prior to 1900 occurred in February 1886. It is possible that this flood equaled or even exceeded the recent floods of 1955 and 1968. Other noteworthy floods of the period occurred in 1807 and 1818.

c. Recent Floods

Five significant floods have occurred on the Charles River in recent years: March 1936, July 1938, August 1955, March 1968 and March 1969. Table D-7 summarizes the peak discharges for the five floods at each of the USGS gaging stations. A brief description of each is given in the following paragraphs:

(1) March 1936

This flood resulted from a combination of runoff from melting snow and heavy rainfall from two major storms over the watershed. Rainfall amounts for the combined storms ranged from about 4.5 inches

TABLE D-5

STREAMFLOW RECORDS

<u>Location of Gaging Station</u>	<u>Drainage Area (sq. mi.)</u>	<u>Period of Record</u>	<u>Discharge (cfs)</u>		
			<u>Mean</u>	<u>Maximum</u>	<u>Minimum*</u>
Charles River at Charles River Village, Mass.	184	1937-1969	292	3,220	0.9
Mother Brook at Dedham, Mass.	--	1931-1969	77	1,040	0
Charles River at Wellesley, Mass.	211	1959-1969	312	2,410	1.0
Charles River at Waltham, Mass.	227**	1931-1969	368	2,670	0.2

*Minimum daily

**Excludes 23.6 square miles drained by Stony Brook

TABLE D-6

MONTHLY RUNOFF
(cubic feet per second)

Charles River at
Charles River Village, Mass.
D. A. = 184 square miles
Record - 31 years through 1969

<u>MONTH</u>	<u>MEAN</u> ⁽³⁾	<u>MAXIMUM</u>	<u>MINIMUM</u>
January	330	662	71.2
February	383	673	143
March	642	1,164	304
April	577	1,137	175
May	352	746	164
June	206	468	67.2
July	135	1,060	25.2
August	114	956	9.01
September	100	640	7.78
October	121	600	13.4
November	226	892	38.4
December	300	685	60.3
ANNUAL	292	466 ⁽¹⁾	122 ⁽²⁾

(1) Water year 1956

(2) Water year 1965

(3) Adjusted for Diversion

TABLE D-7

PEAK DISCHARGES OF MAJOR FLOODS

	Peak Discharge in cfs				
	Mar. 1936	Jul. 1938	Aug. 1955	Mar. 1968	Mar. 1969
Charles River at Charles River Village	3,170	3,110	3,220	3,220	1,930
Mother Brook at Dedham	900	909	970	1,040	580
Charles River at Wellesley	--	--	--	2,410	1,530
Charles River at Waltham	2,540	2,180	2,490	2,670	1,800

in the lower watershed to an excess of 7 inches in the upper watershed. A peak discharge of 3,170 cfs was recorded at the USGS gaging station at Charles River Village.

(2) July 1938

During a 7-day period from 18 to 24 July torrential rains fell throughout the Charles River watershed resulting in record flood levels along the main stem. Rainfall amounts in the lower watershed ranged from 9 to 10 inches, while several locations in the upper watershed recorded amounts from 11 to 14 inches.

(3) August 1955

This flood, the greatest of record on the Charles River, resulted from record rainfall accompanying hurricane "Diane" falling on ground previously saturated by the precipitation of hurricane "Connie" which occurred only a week earlier. Hurricane "Connie", 11 to 15 August, caused rainfall varying from about 4 to 6 inches over southern New England and ended a period of drought. A week later, on 17 to 20 August, hurricane "Diane" brought rainfall from 11 to 15 inches over the watershed. Rainfall totals at Boston and Chestnut Hill were 12.5 and 13 inches, respectively. At the Charles River Village USGS gage, a peak flow of 3,220 cfs was recorded.

(4) March 1968

Heavy rainfall occurred over southern New England on 17 to 18 March resulting in the second largest flood of record in the lower reaches of the Charles River. Highest amounts of precipitation fell in the area just southwest of Boston with 7.7 inches measured at Blue Hills. The peak discharge recorded at Charles River Village was 3,220 cfs equaling the previous high established in August 1955. New maximum discharges were recorded at the USGS gaging stations on the Charles River at Wellesley and Waltham. Antecedent moisture conditions were high in the basin prior to the storm event due to spring snowmelt.

(5) March 1969

The winter of 1968-1969 resulted in record amounts of snow cover throughout the entire New England area. By mid-March, the water equivalent in the snow packs ranged up to 4 inches in the headwaters of the Charles River. On 25-26 March, warm temperatures and rainfall amounts of up to 2.5 inches throughout southern New England

produced minor flooding in the lowlands of the Charles River. A peak discharge of 1,930 cfs was recorded at the USGS gage at Charles River Village on 29 March.

8. FLOOD PROFILES

Flood profiles and a tabulation of high water elevations for the floods of March 1936, July 1938, August 1955 and March 1968 are shown on three plates. Plate D-4 extends from the mouth to river mile 28; plate D-5 covers from river mile 28 to 60; and plate D-6 extends from river mile 60 to the headwaters at Echo Lake.

9. DROUGHTS

a. General

The long term normal rainfall in the Charles River watershed of approximately 44 inches is actually the average of many highs and lows. When rainfall is below average for a period of time the area experiences what is referred to as a "drought". In this case a drought is defined as a prolonged period of precipitation deficiency which seriously affects both riverflow and surface water supplies.

b. Drought of 1961-1966

The recent drought of the mid 1960's resulted in the lowest sustained flows of record in the Charles River. The annual average discharges at Charles River Village were below normal from water years 1962 to 1967 with the lowest occurring in water year 1966. Data on runoff and rainfall deficiencies during these drought years is shown in table D-8 and D-9.

Plate D-8 shows the average monthly flows at the Charles River Village gage for the calendar years 1964, 1965 and 1966 as compared with the average monthly flows for the period of record. In normal years, the average flow during the 4-month period from July through October is about 130 cfs. In these three consecutive drought years, the average flow for the same 4-month period dropped to 33 cfs in 1964, 25 cfs in 1965, and 34 cfs in 1966. The lowest single monthly flow occurred in August 1965 with an average of 17.5 cfs. The lowest daily flow during these years was 7 cfs occurring on 24 August 1966.

TABLE D-8

RUNOFF DEFICIENCIES
(In inches)

<u>Water Year</u>	<u>Runoff</u>	Charles River at Charles River Village, Mass	
		<u>Deficiency</u>	
		<u>Annual</u>	<u>Accumulative</u>
Average	25.3 (1937 to 1960)		
1962	23.2	2.1	2.1
1963	22.1	3.2	5.3
1964	18.8	6.5	11.8
1965	11.4	13.9	25.7
1966	9.0	16.3	42.0
1967	21.2	4.1	46.1
1968	23.9	1.4	47.5

TABLE D-9

RAINFALL DEFICIENCY
(in inches)

Year*	Milford, Mass.			Framingham, Mass.			Chestnut Hill, Mass.		
	Rainfall	Deficiency		Rainfall	Deficiency		Rainfall	Deficiency	
		Year	Acc.		Year	Acc.		Year	Acc.
1962	44.2	0.7	0.7	45.5	--	--	47.9	--	--
1963	38.6	6.3	7.0	37.6	6.2	6.2	38.3	6.0	6.0
1964	35.5	9.4	16.4	37.1	6.7	12.9	35.0	9.3	15.3
1965	28.0	16.9	33.3	29.0	14.8	27.7	27.1	17.2	32.5
1966	36.1	8.8	42.1	35.9	7.9	35.6	35.4	8.9	41.4
1967	45.5	+0.6	41.5	47.7	+3.9	31.7	45.8	+1.5	39.9
1968	42.6	2.3	43.8	43.6	0.2	31.9	48.5	+4.2	35.7
Average Annual Rainfall	44.9 (32 years)			43.8 (94 years)			44.3 (96 years)		

*Calendar year

10. HYDROLOGIC ENGINEERING STUDIES

a. General.

The comprehensive study of the basin included a detailed analysis of the hydrology and hydraulics of the watershed. Basic data and procedures used in the analysis, results, and conclusions are briefly described in the following paragraphs. Also included are an analysis of experienced floods, and the effect of valley storage on the record flood. Further hydrologic analyses by the Soil Conservation Service at certain tributaries in the basin are discussed in Appendix F entitled "Upper Charles River Tributaries and Impoundments".

b. Low Flow Analyses.

Flow duration-frequency statistics were computed based on 30 years of discharge records made available by the U. S. Geological Survey for the Charles River Village gaging station. A graphic illustration of the results of this study showing the minimum average flow versus frequency is included on plate D-8.

The prolonged drought of the middle 1960's resulted in the lowest annual run-offs in the 30-year period of record at Charles River Village. The run-off for water year 1966 was 9.0 inches and for 1965, 11.4 inches as compared to the 30-year average of 21.5 inches. These were the lowest values, and when combined with the preceding and following years, also resulted in the lowest 3 and 4 year totals.

c. Storage-yield Dependability.

The lowest flow recorded each year at Charles River Village for durations varying from 1 to 183 days were determined and analyzed statistically by computer to find the relative severity and frequency of occurrence of low flows on the river. The results of this study were then used to determine the amount of augmentation storage that would be required to maintain selected minimum streamflows with varying dependability. The storage-yield frequency graph shown on plate D-8 indicates the relationship for the three variables: (1) storage in day-second-feet per square mile; (2) yield in cubic feet per second per square mile (csm; and (3) percent dependability.

Although this relationship was developed using flows and assumed storages at Charles River Village, it is considered generally applicable for initial investigations and for screening potential sites anywhere in the watershed, provided the respective sites have sufficient watershed to permit refilling their storage each year.

d. Peak Discharge Frequencies.

Peak discharge frequency analyses were performed in accordance with the procedures outlined in EM 1110-2-1450. The method assumes that the logarithmic values of annual peak flows are normally distributed, thereby permitting the application of standard statistical analysis. This enables the discharge-frequency curve to be defined by the mean value and standard deviation of the array of data. Peak discharge frequency curves at the Charles River Village and Waltham gages are shown on plate D-7.

The low discharges and flat slope of the frequency curve for Charles River Village reflects the tremendous modifying effect of the natural storage in the basin. The curves on plate D-7 represent the frequency of outflows from the storage. Although data are not available, the magnitude and frequencies of tributary inflows to the valley storage may vary considerably from the outflow. For example, whereas the 1955 and 1968 flood peaks are the same at Charles River Village, it is very likely that the greater intensity and totals of the rainfall in the 1955 storm produced higher inflow discharges than experienced in 1968. Thus the Charles River Village records may not be a true indicator of flood conditions throughout the watershed.

From all available information, the greatest flood prior to the installation of flow recorders occurred in February 1886. Data contained in the U. S. Geological Survey publication, "Historical Floods in New England", indicate the 1886 event produced an estimated maximum flow of about 4,900 cfs at the Boston Manufacturing Company (Moody Street) dam in Waltham.

e. Analysis of Floods.

(1) General.

Flooding in the Charles River watershed is caused by late winter or early spring storms combined with melting snow, such as the March floods of 1936, 1968, and 1969. Floods may also occur as a result of summer or fall storms such as the event of July 1938 and record flood of August 1955. In addition, local thunderstorms can cause minor inundation on some of the smaller tributaries.

An analysis has been made of the development of floods in the watershed using hydrologic and climatological data associated with the

flood of August 1955. The more recent March floods of 1968 and 1969 have also been utilized in studying specific flood plain areas to determine the effectiveness of natural storage. For purposes of the study, the Charles River was divided into 8 routing reaches between Milford and Waltham, and each reach was subdivided into tributary and local areas. Table D-10 lists the routing reaches, their length and the total drainage area at the end of each reach. A brief description of the major reaches along the Charles River is summarized in the following paragraphs:

(a) Headwaters to Caryville Dam. The first three reaches of the Charles River are upstream of Caryville Dam in Franklin, Massachusetts and have a total combined drainage of about 25 square miles. Echo Lake, Cedar Swamp Pond and Box Pond are located on the main stem within this main reach.

(b) Caryville to Medway Dam. This relatively short reach of river, also in the town of Franklin, intercepts an additional 40 square mile drainage area representing about 60 percent of the drainage area at Medway. The moderate slopes of the principal tributaries, in this reach, tend to retard run-off.

(c) Medway to South Natick Dam. This 20-mile reach of the river lies in the central portion of the watershed, principally in the towns of Norfolk, Millis, Medfield, Sherborn, and Natick. Three of the principal tributaries of the Charles River watershed enter in this reach. The aggregate drainage area of Mill River, Bogastow Brook and Stop River, totaling about 59 square miles, represent nearly 38 percent of the total at South Natick. The extensive amount of natural valley storage in this reach has a large modifying effect on flood discharges from the total 156-square mile drainage area above South Natick Dam. This drainage area represents 85 percent of the total at Charles River Village and 62 percent of the total at Waltham.

(d) South Natick to Charles River Village. This 6-mile reach, principally in Needham and Dover, has three major tributaries, Waban, Fuller and Trout Brooks with a combined drainage area of 21 square miles.

(e) Charles River Village to Waltham. Stony Brook is the largest tributary of this 22-mile reach of river. Within this reach is located Mother Brook through which approximately one-third of the Charles River flow is diverted to the Neponset River Basin.

TABLE D-10

CHARLES RIVER - ROUTING REACHES

<u>Limits of Reach</u>	<u>Distance</u> (miles)	<u>Drainage</u> <u>Area</u> (sq. mi.)
Echo Lake	3.4	
Milford	5.2	7.8
Box Pond Mill	5.6	14.2
Caryville Dam	1.7	24.8
West Medway Dam	2.1	52.6
Medway Dam	19.8	65.0
South Natick Dam	6.8	156.
Charles River Village	21.7	184.
Waltham	12.6	251.
Charles River Dam		305.

(f) Waltham to Charles River Dam. The watershed of this 12-mile reach of river, with a drainage area of 58 square miles, comprises a highly concentrated city and suburban type development resulting in high rates of run-off. The inflow from this local area normally occurs long before the peak flows from the upper watershed. For hydrologic purposes, the Charles River at Waltham is the dividing line between the upper and lower watershed. A detailed hydrologic analysis of the lower watershed is included in the previously referenced Lower Charles River Interim Report.

(2) Flood Routing. The basin was divided into tributary watersheds and sub-areas as shown on plate D-1. Synthetic hydrographs were developed for all ungaged areas from studies of rainfall distribution, run-off characteristics, and recorded hydrographs of comparable gaged areas. Because of its simplicity and its adaptability for component routing, the progressive average-lag method of flood routing was adopted for all reaches except between Medway and South Natick, where a storate routing type analysis was made. The total inflows to each reach were added and routed to obtain the outflow at the lower end of the reach. The routing coefficients were obtained by trial based on the best reproduction of the August 1955 flood hydrographs. The routings were performed on an IBM 1130 computer, utilizing the computer program developed by the Corps of Engineers Hydrologic Engineering Center (HEC) in Davis, California. Limits of the routing reaches and the adopted progressive average-lag coefficients are shown in table D-11.

TABLE D-11

ROUTING COEFFICIENTS
CHARLES RIVER WATERSHED

<u>Limits of Reach</u>	<u>Routing Period</u> (hrs)	<u>Average</u> (periods)	<u>Lag</u> (periods)
Echo Lake Dam	3	5	1
Milford	3	6	3
Box Pond Dam	3	10	4
Caryville Dam	3	17	2
West Medway Dam	3	15	3
Medway Dam	(Routed through valley storage)		
South Natick Dam	3	3	3
Charles River Village			

The natural valley storage in the reach extending from Medway Dam to the South Natick Dam, a distance of nearly 20 miles, is the most important reach in the watershed with respect to its modifying effect on floods. Plate D-11 shows the large area that is inundated during major floods and the profile of the high water elevations. Flood stages, between 7 and 8 feet above normal, result in about 3,200 acres of inundation. This flooding in the area represents a storage estimated to be between 20,000 and 25,000 acre-feet, equivalent to about 3 inches of run-off from the watershed of 156 square miles. Additional natural storage takes place on tributaries, particularly the Great Black Swamp on Bogastow Brook.

The August 1955 event was used as the benchmark flood for watershed storage analysis, however, as the March 1968 flood hydrograph at Charles River Village was practically identical in magnitude and shape as the 1955, the analysis, with respect to watershed storage, including those experienced in March 1936 and July 1938, were similarly affected by watershed storage. Hydrographs of inflow and outflow at various reaches along the main stem of the Charles River are shown on Plate D-9.

(3) Flood Discharges. Of the reaches studied, the highest rate of discharge per square mile (csm) during the 1955 flood occurred at Milford near the headwaters of the Charles River with a peak of 141 csm. Higher rates probably were experienced on upper tributaries before being modified by valley storage. The highest discharge on the main river occurred at Medway with an estimated peak of 3,800 cfs (58.5 csm). The extensive valley storage below this point had a tremendous reducing effect on the peak flow and the maximum discharge at Charles River Village was 3,220 cfs, equivalent to only 17.5 csm. The peak at Charles River Village came on the afternoon of 23 August 1955, about 4-1/2 days after the flood producing storm on 18 and 19 August.

The high flow at Waltham was of long duration but occurred on the 19th due to the removal of flashboards on the Moody Street Dam and the high local urban run-off. Peak flow from the upper watershed did not arrive in Waltham until 24 August. Charles River flows below Newton Upper Falls were significantly reduced by the diversion of nearly 1,000 cfs through Mother Brook Diversion. A peak discharge profile for the August 1955 flood is shown on Plate D-9. Following is a list of maximum flows at selected locations along the river:

<u>Location</u>	<u>Drainage Area</u> (sq. mi.)	<u>Discharge</u> (cfs)	<u>Discharge</u> (cfs/sq.mi.)*
Milford	7.8	1,000	141.
Caryville	24.8	2,200	88.5
Medway	65.0	3,800	58.5
Natick	156.	2,800	17.9
Charles River Village	184.	3,220	17.5
Waltham (19 August)	251	2,490	9.9**
Waltham (23 August)	251	2,380	9.5**

*Cubic feet per second per square mile

**Affected by diversion at Mother Brook

The March 1968 flood was very similar to the August 1955 flood in magnitude. The peak flow of 3,220 cfs at Charles River Village was the same for both floods. The 1968 flood crests downstream were slightly higher than 1955 due to channel improvement following the 1955 flood resulting in less utilization of valley storage in the Needham-Dedham area. Peak flows of 2,410 cfs at Wellesley, 2,620 cfs at Waltham and a diversion of 1,040 cfs at Mother Brook were measured at U. S. Geological Survey gaging stations in March 1968. It is interesting to note that peak discharges between 3,110 and 3,220 cfs have been experienced four times since 1936 at Charles River Village. Such consistent maximum flows are comparable to the regulated discharges from an ungated flood control dam.

(4) Standard Project Flood. The standard project flood is a synthetic flood developed by the Corps of Engineers and used as a criteria in the design of local protection projects involving dikes and walls. Such a flood was not developed for the Charles River in the study since no local protection projects were proposed. The standard project storms (SPS) rainfall for the Charles River watershed, as described in Engineering Bulletin 52-8, is 12.8 inches, or 0.7 inch less than the August 1955 storm total of 13.5 inches. The peak discharge resulting from an SPS rainfall would depend a great deal on antecedent conditions. For example, the peak discharges in March 1968 were comparable to those in 1955 and resulted from a storm rainfall of only 5.5 inches coincident with snow-melt. However, the March 1968 flood occurred in late winter with high antecedent run-off conditions in the basin and the August 1955 rainfall occurred in the summer with low antecedent conditions in the swamps and high evapotranspiration rates. Future development of a standard project flood for the design of dikes or walls will require an estimate of maximum probable antecedent conditions as well as probable loss of natural valley storage. Each of these estimates will have considerable bearing on the resulting discharge and over-all safety of design.

f. Analysis of Natural Valley Storage.

(1) General. Natural valley storage along the main stem of the Charles River and its tributaries, particularly in the 20-mile reach extending from the Medway Dam to the South Natick Dam, is considered vital to the natural control of floods on the Charles River. The August 1955 inflow and outflow hydrographs for the reach above the South Natick Dam, shown on plate D-9, demonstrate the tremendous effect of the extensive natural valley storage in controlling floods. The maximum total inflow to the reach was estimated to be at least 8,000 cfs occurring on 20 August. The natural storage reduced and retarded the peak outflow to 2,800 cfs at the South Natick Dam occurring on the 23rd. This storage not only served to reduce the peak flows by 65 percent, but desynchronized the peaks lagging the peak outflow by about 3 days. Maximum floodflows, in terms of cubic feet per square mile (csm) are exceedingly low in the Charles River when compared with adjacent river basins such as the Blackstone. The peak discharge at Charles River Village was only 17.5 csm in 1955 compared with 121 csm experienced on the nearby Blackstone River at Northbridge.

At the U. S. Geological gaging station at Charles River Village the maximum discharges occur about 4 days after the flood producing storm and it takes 3 to 4 weeks for the flow to return to normal. In August 1955, about 50,000 acre-feet of flow occurred after the peak discharge, most of this coming from the water stored in the wetlands and lakes. This is equivalent to about 5 inches of run-off from the drainage area of 184 square miles.

(2) Storage Versus Flood Discharge. By basic hydrograph analysis a study was made to determine the effect of loss of natural valley storage on flood discharges. Plate D-12 graphically illustrates derived hydrographs for the August 1955 flood at Charles River Village assuming varying percentages of loss of upstream storage. Using the 1955 flood hydrograph as a base, a series of characteristic hydrographs were developed empirically with comparable volumes but with higher peaks and shorter times of concentration. Since the area between the developed and natural hydrographs represented the required change in natural valley storage, intervening areas were determined for a series of curves, thereby developing a relationship between loss of storage and resulting increase in peak discharge. Included on plate D-12 is a curve in which percent reduction in natural storage is plotted against peak discharges at Charles River Village. Tabulated below is the percent loss in storage associated with the peak discharges of the various hydrographs.

<u>Peak Discharge</u> (cfs)	<u>Loss of Storage</u>		<u>Percent Loss</u>
	<u>Acre-Feet</u>	<u>Inches</u>	
3,220(1955)	0	0	0
4,500	11,000	1.1	22
6,000	20,000	2.0	40
9,000	32,000	3.3	66
12,000	39,000	4.0	80
15,000	44,000	4.5	90
18,400*	50,000	5.0**	100

*Assuming 100 csm

**Estimated storage utilized in 1955 flood

As indicated in the preceding table and illustrated on Plate D-12, existing upstream storage is of great value in the natural control of floods. Loss of this natural valley storage is a real threat with the increasing demand for land in the area. Loss could result from either filling or by improved drainage of swamplands. Increased development, taking place in the watershed, will progressively increase the rate and value of surface run-off to the streams. Present vegetated areas will be replaced with asphalt greatly increasing the frequency and magnitude of run-off to the swamps. Therefore, the swamps, retained in their natural poorly drained state, will grow in value as a natural flood control reservoir.

If the swamps are not retained, replacement of storage by man-made reservoirs in the basin will be physically and economically prohibitive. The alternative of protecting downstream properties by the construction of dikes and walls will be extremely costly and undesirable from an aesthetic point of view.

(3) Effectiveness of Proposed Plan. As presented in the main report, the proposed plan of action consists of preserving 17 wetland* areas totaling about 8,500 acres. The selected wetland areas have a minimum of 100 acres and collectively have a major effect on flood run-off. Storage in these areas during the August 1955 flood was estimated to represent at least 75 percent of the total natural flood storage in the

*Area A, Beaver Brook, which is less than 100 acres is to be restudied during the advance engineering and design stage and has not been included in this hydraulic analysis.

watershed. However, it is not the total storage and it is hoped and expected that the Inland Wetland Act and local town ordinances will restrict other smaller areas.

The relative increase in discharge versus loss of storage curve shown on plate D-12 was used to develop adjusted discharge frequency curves at potential downstream damage centers for a range of percent loss of storage values up to 40 percent. In determining benefits of the proposed plan it was assumed that 75 percent of the increase in discharge due to loss of storage would be prevented by preserving 75 percent of the total storage area in the basin. Adjusted stage-frequency curves for the Charles River at Mother Brook in Dedham are shown on plate D-13.

g. Analysis of Other Projects.

(1) Metropolitan District Commission Flood Control Projects. Following the major flood of August 1955 on the Charles River, the Metropolitan District Commission initiated channel improvements in Newton Upper Falls from the Silk Mill Dam to the Kendrick Street Bridge. The improvements included installation of a bascule gate at the dam and extensive channel excavation from the dam to Kendrick Street Bridge, a distance of 2 miles. Simultaneously with this work, a bascule gate was also installed at the entrance to Mother Brook diversion. The 1968 flood provided an excellent opportunity to evaluate the effect of the improvements by comparison of discharges and the flood profiles, particularly in the flood plain area of Newton, Needham and Dedham.

(a) Operation of Bascule Gates During March 1968 Flood. The March 1968 flood produced the highest discharges since completion of bascule gates at the Silk Mill Dam and Mother Brook, and the improvement of the channel from the dam to Kendrick Street Bridge. Prior to the flood, the top of the gates were elevation 84.50 feet msl at the Silk Mill Dam, and 84.07 at Mother Brook (normal settings of the Silk Mill and Mother Brook dams are considered to be 84.5 and 84.4 feet msl, respectively). The Silk Mill Dam gate was lowered 8 inches to elevation 83.83 feet about noon on 21 March. Lowering the gate caused the discharge to increase rapidly from 2,000 to 2,410 cfs.

The bascule gate at Mother Brook was raised about 4 inches on 21 March. Maximum diverted flow to the brook was 1,040 cfs occurring on the 21st just before the gate was raised.

(b) Flood Profile. The top of the bascule weir at the Silk Mill Dam is 6 inches higher than the crest of the former dam. Before the gate was opened on 21 March 1968, the water level at the dam was approximately the same as the highest elevation experienced in 1955. However, in the upstream flood plain, extending from Newton to Needham and Dedham, the highest flood stages in 1968 were considerably lower than in 1955. The reductions varied from 4 feet at Kendrick Street Bridge to about 2 feet at Route 128 Bridge. This reduction is almost entirely attributable to the channel excavation in the 2-mile section from the dam to Kendrick Street. The excavation, varying in depth from 6 to 6.5 feet for over half the length of the improvement, radically changed the stage-discharge relationship for the river resulting in much lower flood elevations in the flood plain.

(c) Effect of Improvements. The bascule weir and channel improvement had the following effects on the 1968 flood as compared with the 1955 event:

1. Significant reduction in flood stages in Newton, Needham, West Roxbury, and Dedham. Greater reductions could have been obtained had the bascule weir been lowered earlier.

2. Use of natural flood plain storage was reduced about 5,000 acre-feet.

3. Loss of storage affects outflow from the flood plain in two ways:

a. The initial flood run-off is not retarded by storage, hence there is a higher contribution to downstream flows immediately after the rainfall. Twelve hours after the storm, the 1968 discharge at the Silk Mill was 1,740 cfs compared with an estimated 1,090 cfs in 1955. These higher discharges had an adverse effect in increasing the early discharges in the lower Charles and the Neponset Rivers.

b. Maximum discharges at Charles River Village and the Silk Mill Dam generally originate from run-off in the upper watershed and crest about 4 days after the storm. The rate of rise is so gradual during the 48-day period preceding the crest that the loss in flood plain storage has little effect on the maximum total outflow. Assuming no gate operation at the Silk Mill Dam in 1968, the total outflow would have been an estimated 3,300 cfs compared with 3,170 cfs in 1955.

(d) Effect of Gate Operation in 1968. Lowering the bascule gate at the Silk Mill Dam on 21 March 1968 caused the discharge to increase from 2,000 cfs to 2,410 cfs at the dam. This contributed to a record high discharge of 2,650 cfs on March 22 at Waltham. Lowering the bascule gate at Silk Mill Dam checked the rise of diversion flow at Mother Brook which peaked at 1,040 cfs. It is estimated that the flow would have increased to about 1,100 cfs on Mother Brook, assuming there had been no gate operation at the Silk Mill Dam.

(e) Conclusion.

1. The Metropolitan District Commission project consisting of channel improvement in Newton between Silk Mill Dam and Kendrick Street Bridge, and the bascule gates at the Silk Mill Dam and the control works at Mother Brook, has a substantial effect in lowering flood stages in the flood plain bounded by Newton, West Roxbury, Needham, and Dedham.

2. The value of the flood plain storage in retarding outflow has been reduced.

3. This adverse feature of the project particularly affects the early phase of flood development. The area above Newton Upper Falls now contributes higher discharges to coincide with the rapid urban run-off in Newton, Waltham, and Watertown. Similarly, Mother Brook diverts more water to the Neponset River.

(2) Mother Brook Diversion. Approximately one-third of the Charles River flow is normally diverted from the Charles to the Neponset River through the Mother Brook diversion. The original purpose of this diversion was entirely for industrial water use and was unrelated to flood regulation. In 1831 an agreement was reached whereby it was decided that the mill owners on Mother Brook and the Neponset River should have the right to divert one-third of the flow of the Charles River, the other two-thirds would pass down to the mill owners on the Charles River. It is obvious, however, that such diversion does have a significant modifying effect on floodflows on the Charles River downstream of the diversion.

Although this report was concerned primarily with the Charles River, some consideration was given to the effect of floodflow diversions on Mother Brook and the Neponset River. These are described as follows:

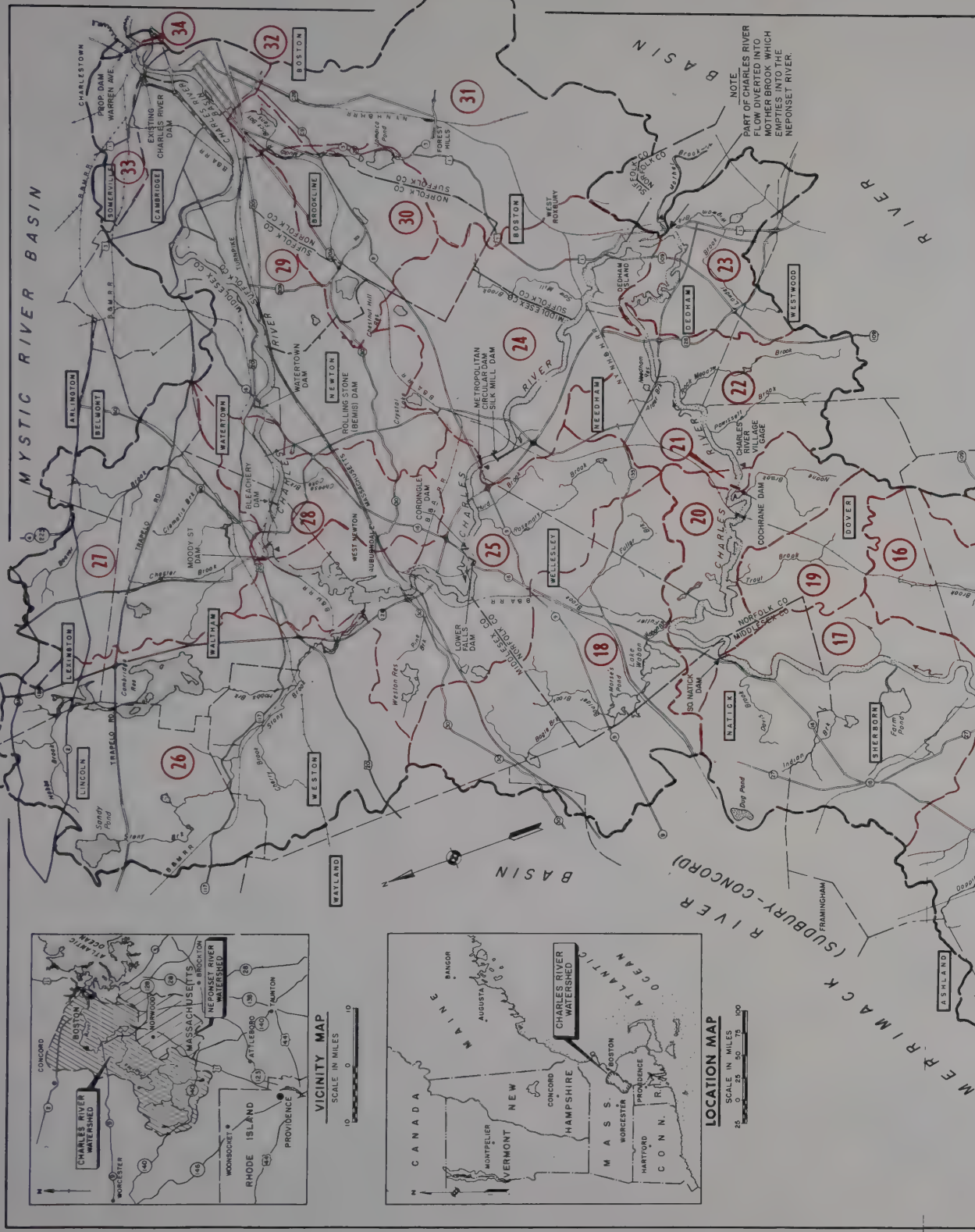
(a) Mother Brook. The 1968 flood demonstrated that the non damaging capacity of the brook is approximately 1,000 cfs. Apprehension by abutters about rising stages caused the MDC to raise the weir and check the rate of diversion. Should larger floods originate in the Charles River from urban development, consideration should be given to modifying the legislative act to limit the maximum rate of diversion to 1,000 cfs.

The use of Charles River water in industrial plants on Mother Brook has ceased. The only water user today is the Tileston-Hollingsworth company on the Neponset River, located about 1 mile downstream of Mother Brook. Should this plant be abandoned in the future, or cease to use river water, the legislative act should be reviewed with respect to the one-third diversion. Modification of this requirement would allow higher low flows in the lower Charles River and help in improving the quality of the water.

(b) Neponset. Although flood data for the lower Neponset River is meager, studies indicate that the diverted flood-flows from the Charles River are a major contribution to the flood peak downstream of Mother Brook. In the March 1968 flood it is estimated that approximately two-thirds of the flood peak at the Tileston-Hollingsworth Dam (MDC) was the diverted flow from the Charles River. If there had been no diversion, the peak would have probably occurred at another time, but it still would have been only an estimated 50 percent of what was experienced. However, due to channel hydraulics and the large storage capacity of the Fowl Meadows, the Mother Brook flows have no significant effect on river stages or the run-off from the watershed upstream of Paul's Bridge.

A program to collect more basic data on the flood run-off in the lower Neponset River and periodic review of regulation procedures for the bascular weirs at the Silk Mill Dam and the entrance to Mother Brook is needed in order to obtain optimum flood stage reductions on both the Charles and Neponset Rivers

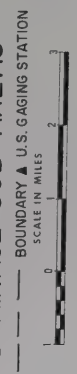
MERRIMACK RIVER BASIN
(SHAWSHOEN)



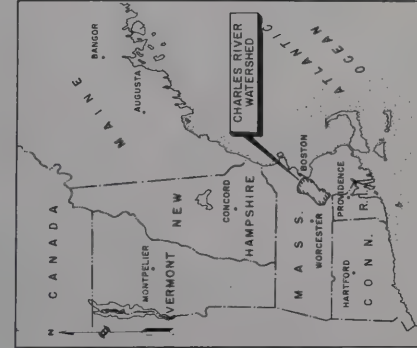
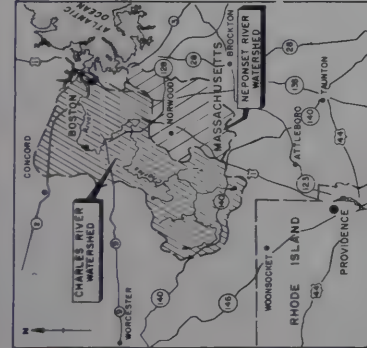
CHARLES RIVER
DRAINAGE SUB-AREAS

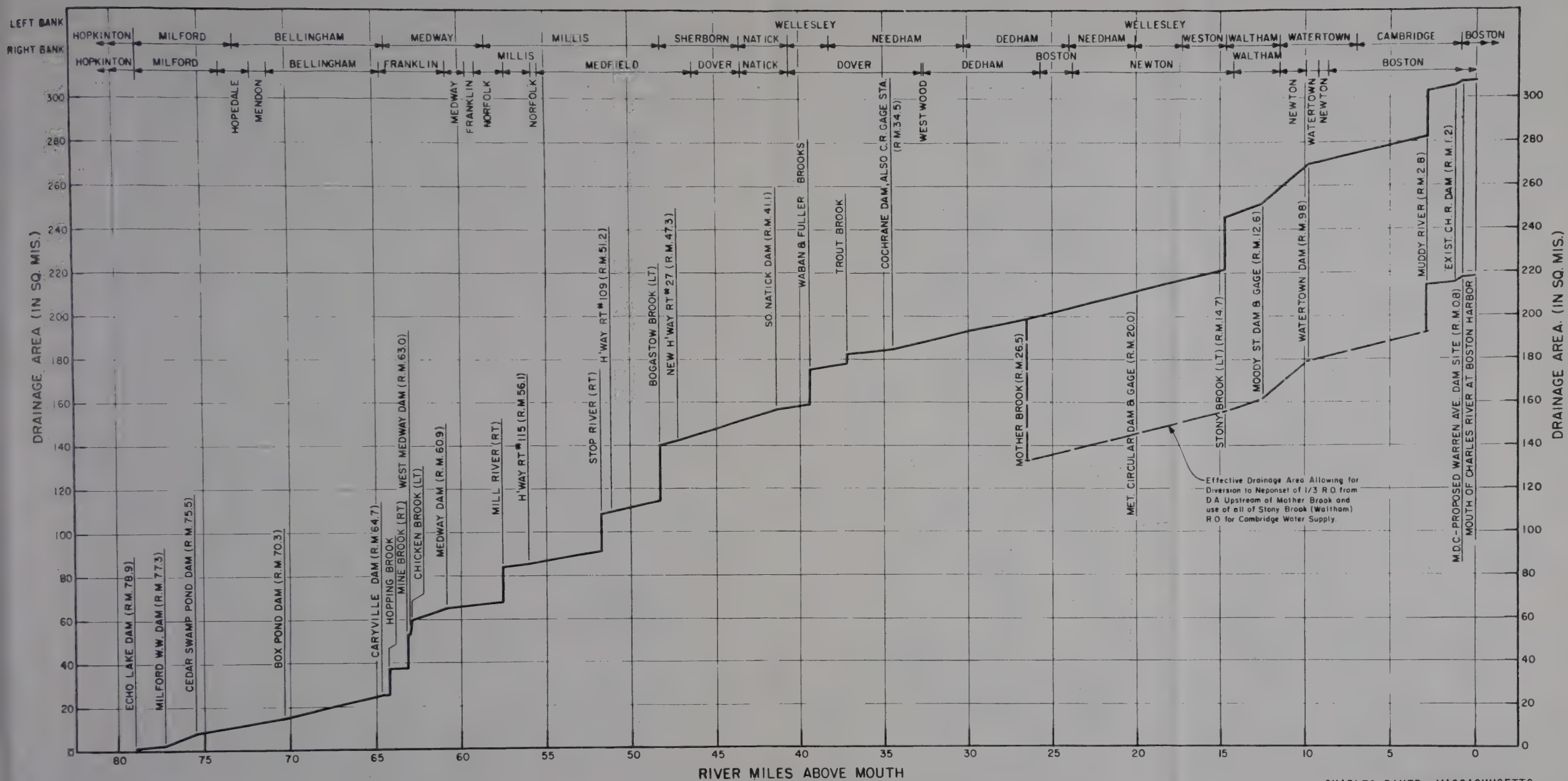
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1	1.4	18	16.1
2	8.9	19	4.6
3	5.5	20	7.1
4	6.4	21	0.1
5	10.6	22	0.7
6	24.8	23	5.5
7	11.5	24	13.1
8	15.7	25	211.3
9	9.6	26	14.3
10	7.8	27	23.6
11	5.4	28	11.2
12	16.3	29	4.8
13	3.9	30	18.2
14	17.1	31	6.1
15	6.4	32	13.9
16	25.5	33	1.1
17	7.1	34	304.6
18	14.8	CHARLES R. DAM 304.6	
19	156.1	MOUTH (U.S. NAVY YARD) 307.4	
20		SD. MOUTH DAM 156.1	

CHARLES RIVER STUDY
MASSACHUSETTS
DRAINAGE SUB-AREAS



DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.

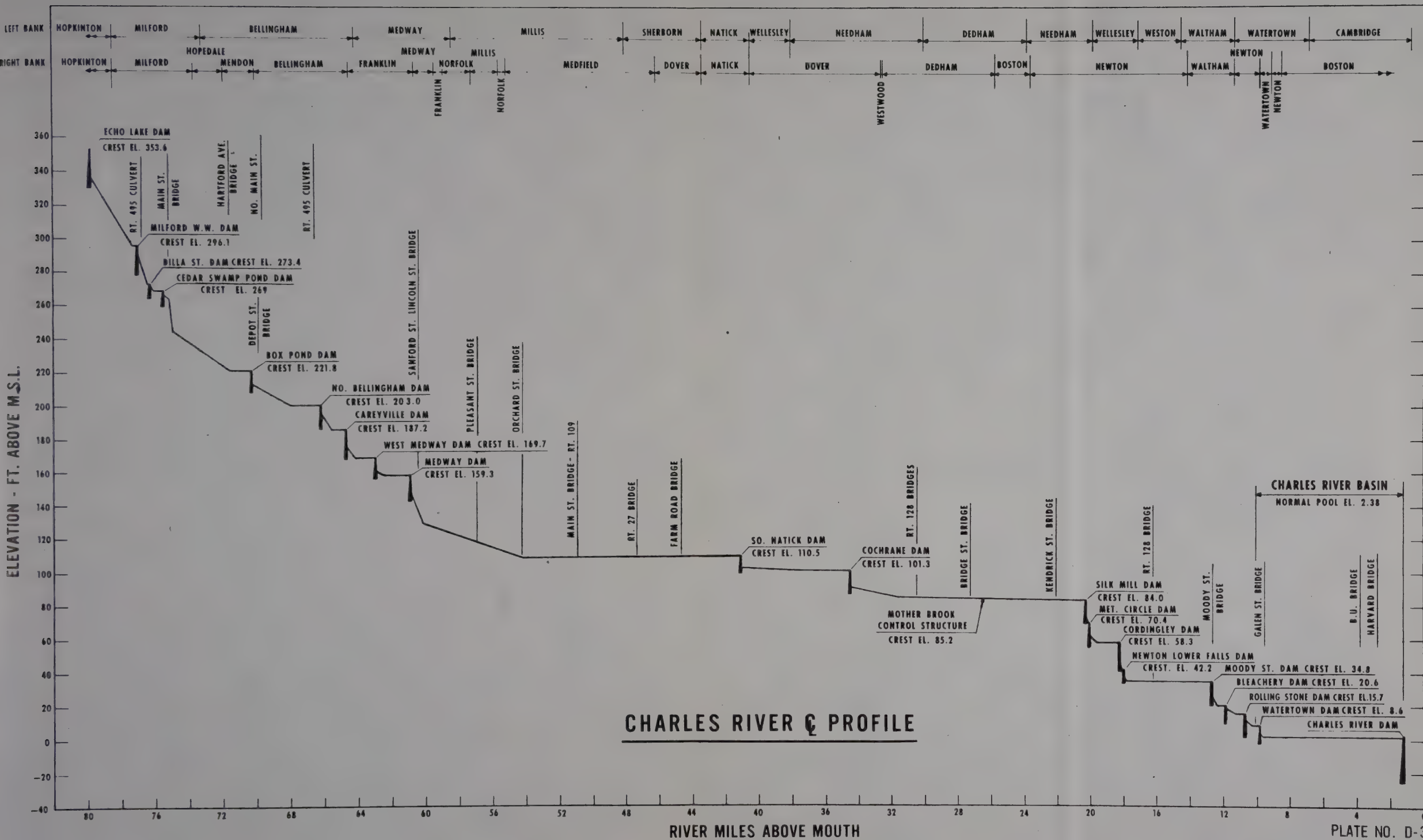




CHARLES RIVER, MASSACHUSETTS
 CUMULATIVE DRAINAGE AREA

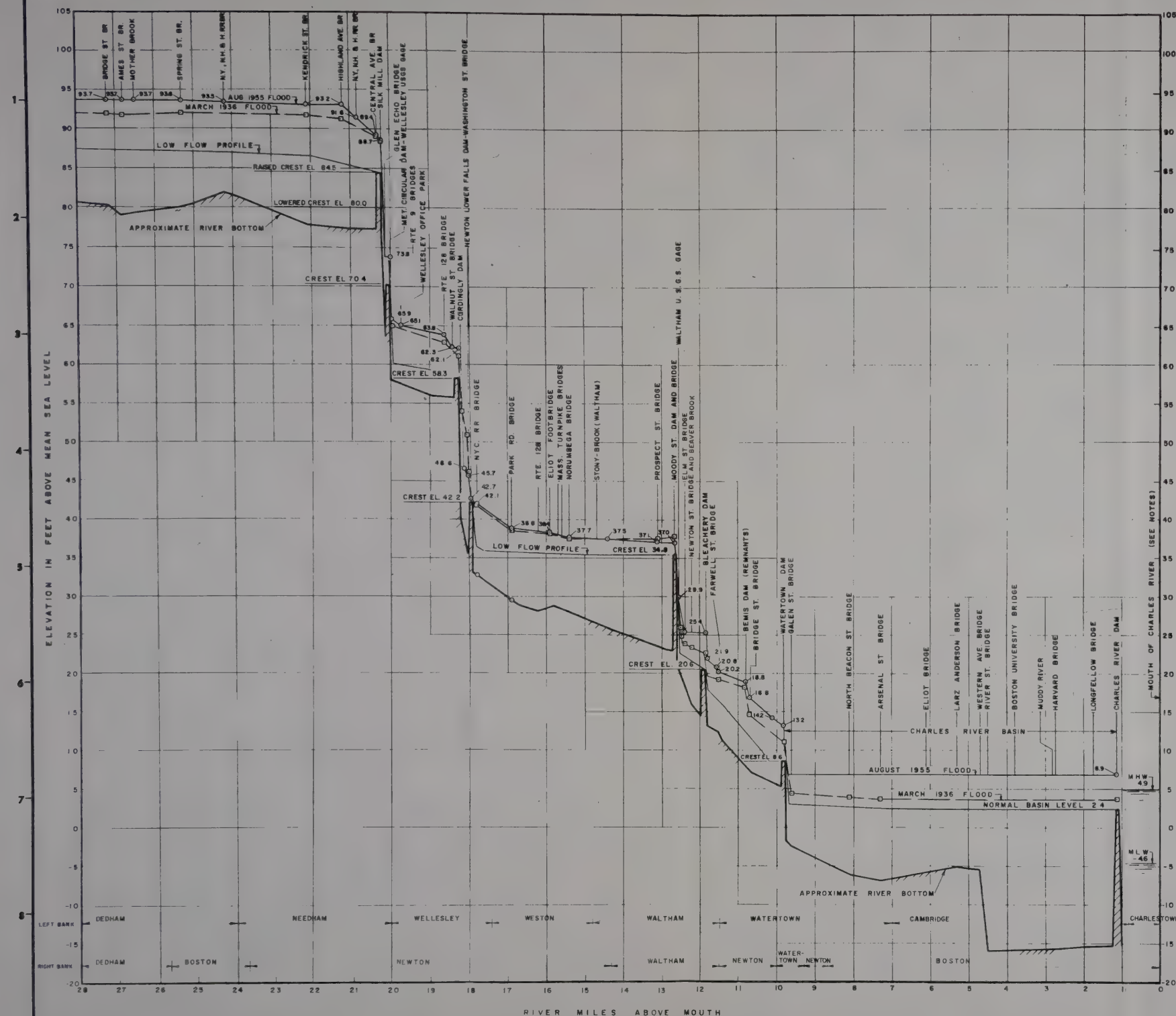
AUGUST 1967
 PREPARED BY
 DEPARTMENT OF THE ARMY
 NEW ENGLAND DIVISION, CORPS OF ENGINEERS

ELEVATION - FT. ABOVE M.S.L.



CHARLES RIVER & PROFILE

RIVER MILES ABOVE MOUTH



CHARLES RIVER FLOOD ELEVATIONS
RIVER MILE 0 TO 28
(Elevations in Feet Above Mean Sea Level)

RIVER MILE	LOCATION	MARCH 1936	JULY 1938	AUGUST 1955	MARCH 1968
1.2	CHARLES RIVER DAM	3.7	3.4	6.9	5.8
9.6	GALEN STREET BRIDGE	4.4	-	-	5.4
9.8	WATERTOWN DAM	11.2	-	13.2	11.1
10.7	BRIDGE STREET BRIDGE	14.6	15.1	18.8	19.2
11.5	FARWELL STREET BRIDGE	19.3	19.7	20.8	21.5
11.8	WALTHAM BLEACHERY DAM	22.7	23.0	25.4	-
12.2	NEWTON STREET BRIDGE	23.4	-	-	24.34
12.4	ELM STREET BRIDGE	23.9	-	26.4	-
12.5	USGS GAGE - WALTHAM	24.8	24.6	25.4	25.2
12.6	MOODY STREET DAM	27.8	-	27.0	-
12.6	MOODY STREET BRIDGE	27.8	26.3	27.0	-
13.1	PROSPECT STREET BRIDGE	27.5	-	27.1	-
15.4	NORUMBEGA STREET BRIDGE	27.5	26.3	27.7	-
15.9	ELIOT FOOTBRIDGE	28.2	-	28.4	-
16.9	PARK ROAD BRIDGE	28.6	27.9	28.8	28.04
17.8	NYC RAILROAD BRIDGE	-	-	42.1	-
17.9	WASHINGTON STREET BRIDGE	41.9	45.5	42.7	-
17.9	NEWTON LOWER FALLS DAM	46.2	-	45.7	46.1
18.2	CORDINGLEY DAM	61.2	60.0	62.1	-
18.4	WALNUT STREET BRIDGE	-	60.2	62.3	62.1
18.6	ROUTE 128 BRIDGE	-	-	63.8	-
19.7	WELLESLEY OFFICE PARK	-	-	-	65.2
20.0	USGS GAGE - WELLESLEY	-	-	-	74.1
20.0	ROUTE 9 BRIDGE	65.0	-	65.9	-
20.0	METROPOLITAN CIRCULAR DAM	73.4	-	73.8	74.1
20.1	GLEN ECHO BRIDGE	73.4	-	73.8	-
20.2	SILK MILL DAM	88.5	-	88.7	-
20.3	CENTRAL AVENUE BRIDGE	89.2	91.3	89.4	88.3
20.8	NYNHAM RAILROAD BRIDGE	90.3	-	91.6	-
21.2	HIGHLAND AVENUE BRIDGE	91.4	-	93.2	88.9
22.1	KENDRICK STREET BRIDGE	91.8	-	93.2	89.4
24.2	NYNHAM RAILROAD BRIDGE	-	-	93.5	-
25.3	SPRING STREET BRIDGE	92.1	92.7	93.6	-
26.5	MOTHER BROOK	91.3	-	93.7	89.6
26.8	AMES STREET BRIDGE	91.9	-	93.7	-
27.2	BRIDGE STREET BRIDGE	92.0	93.0	93.7	90.6

* DOWNSTREAM

NOTES:

MILE 0.0 ASSUMED AS INTERSECTION OF CENTER LINES OF CHARLES RIVER AND BOSTON INNER HARBOR CHANNEL.
 O OBSERVED AUGUST 1955
 A OBSERVED MARCH 1968
 □ OBSERVED MARCH 1936
 ALL ELEVATIONS IN FEET ABOVE M.S.L.
 ELEVATIONS OF THE MARCH 1968 FLOOD ARE UPSTREAM OF BRIDGES UNLESS OTHERWISE NOTED.

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

CHARLES RIVER STUDY FLOOD PROFILES RIVER MILE 0 TO 28

CHARLES RIVER, MASSACHUSETTS

DES. BY: O.D.E.J.R.
SUBMITTER:
CHECKED: SECTION
APPROVAL RECOMMENDED:
REVIEWED: CHIEF, TECH. ENG. BRANCH
PROJECT ENGINEER:
APPROVAL RECOMMENDED:
CHIEF, BRANCH

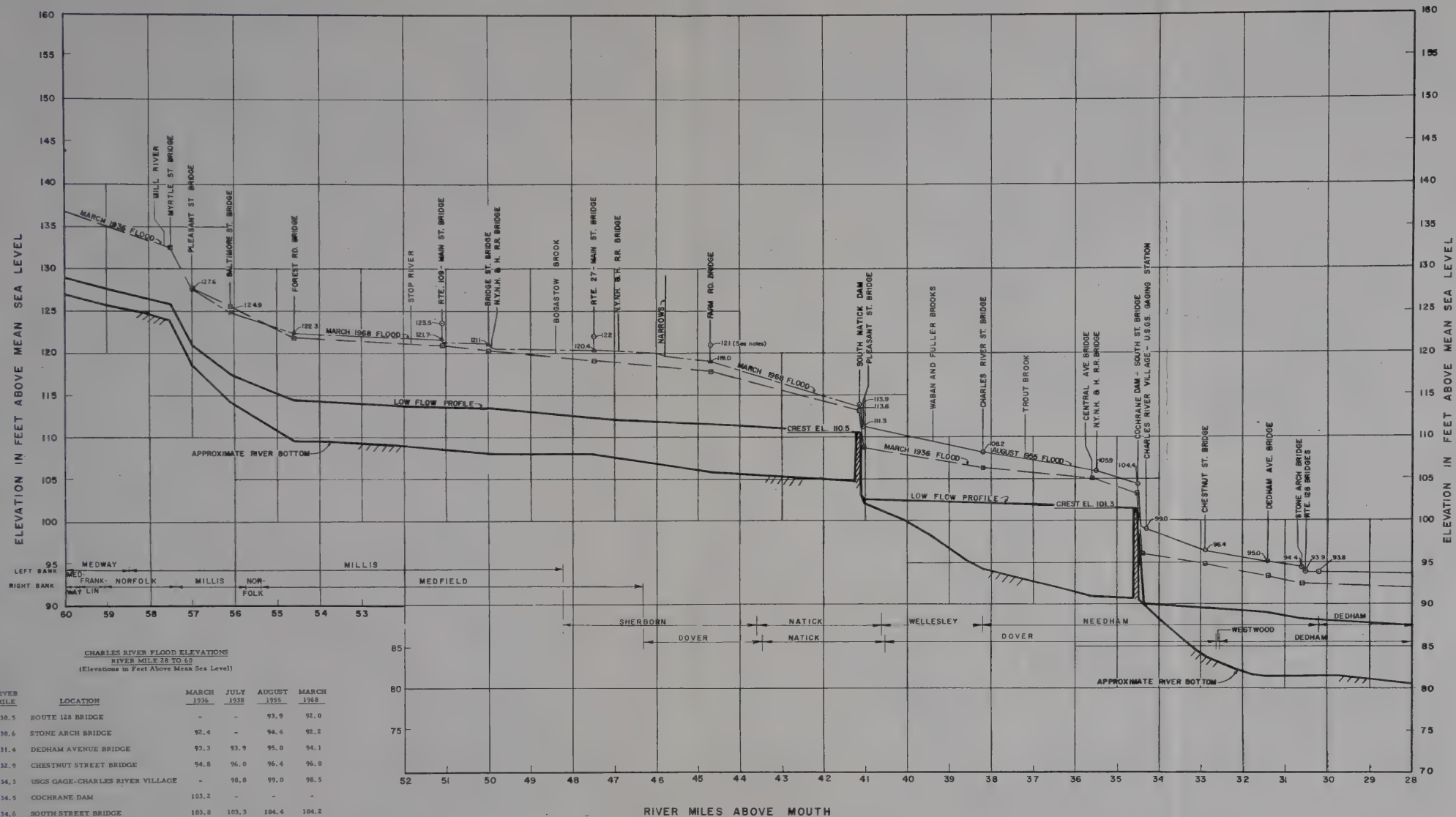
APPROVED: DATE:

CHIEF, ENGINEERING DIVISION

SCALE: SPEC. NO.:

DRAWING NUMBER:

SHEET



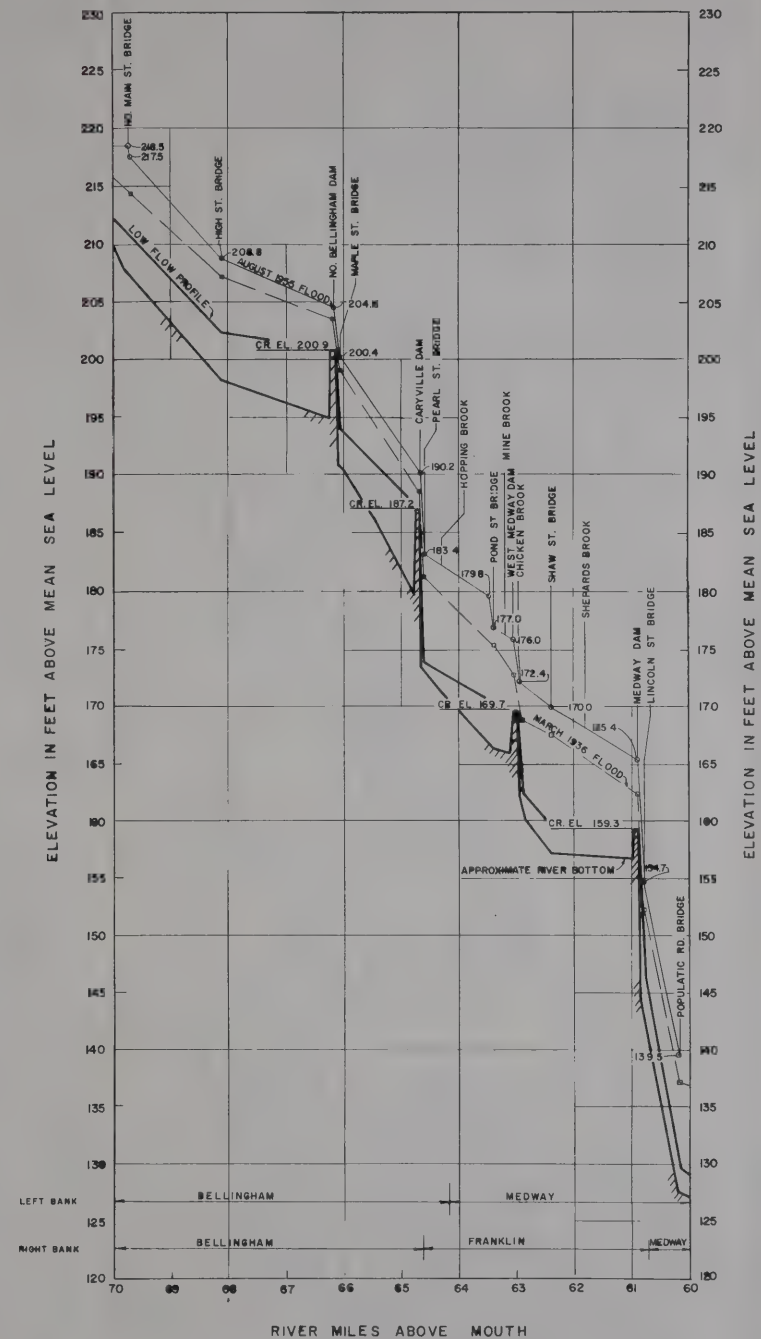
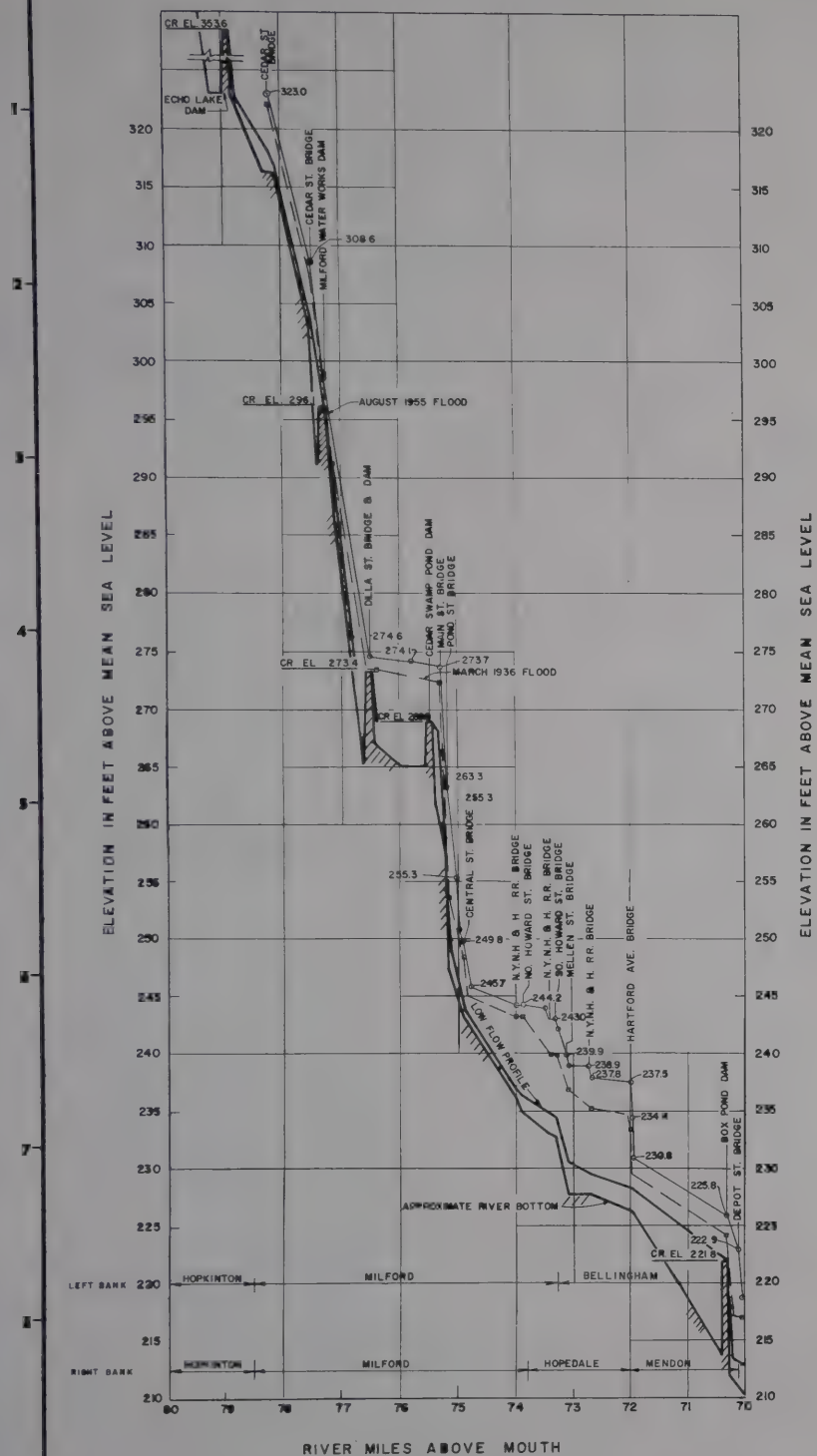
NOTES:

○ OBSERVED AUGUST 1955
△ OBSERVED MARCH 1968
□ OBSERVED MARCH 1936

ELEVATIONS OF THE MARCH 1968 FLOOD ARE UPSTREAM OF BRIDGES UNLESS OTHERWISE NOTED

SPOT ELEVATIONS OF THE AUGUST 1955 FLOOD BETWEEN SOUTH NATICK AND MEDWAY DAMS ARE BASED ON THE ACCOUNTS OF WITNESSES AS REPORTED IN 1969 AND ARE NOT CONSIDERED SUFFICIENTLY RELIABLE TO ESTABLISH A DEFINITE FLOOD LINE.

DEPARTMENT OF THE ARMY NEW ENGLAND DIVISION CORPS OF ENGINEERS WALTHAM, MASS.			
CHARLES RIVER STUDY FLOOD PROFILES RIVER MILE 28 TO 60			
DES. BY		COL. BY	
SUBMITTED		REVISION	
CHECKED		APPROVED	
APPROVAL RECOMMENDATION		DATE	
PROJECT ENGINEER		CHIEF, HYDRAULIC DIVISION	
SCALE		SPEC. NO.	
SHEET		DRAWING NUMBER	



CHARLES RIVER FLOOD ELEVATIONS
RIVER MILE 60 TO 80
(Elevations in Feet Above Mean Sea Level)

RIVER MILE	LOCATION	MARCH 1936	JULY 1938	AUGUST 1955	MARCH 1958
60.2	POPULATIC ROAD BRIDGE	137.2	138.8	139.5	138.4
60.8	LINCOLN STREET BRIDGE	152.3	153.2	154.7	-
60.9	MEDWAY DAM	162.4	-	165.4	162.5
62.4	SHAW STREET BRIDGE	167.6	168.7	170.0	-
63.0	WEST MEDWAY DAM	172.9	-	175.0	-
63.4	POND STREET BRIDGE	175.4	-	179.8	176.3
64.7	PEARL STREET BRIDGE	181.4	-	183.4	-
64.7	CARYVILLE DAM	188.7	189.8	190.2	-
66.1	MAPLE STREET BRIDGE	199.2	199.9	200.4	199.0
66.2	NORTH BELLINGHAM DAM	203.7	204.5	204.6	-
67.2	ROUTE 495 BRIDGE	-	-	-	-
68.1	HIGH STREET BRIDGE	207.3	208.1	208.8	-
69.7	NORTH MAIN STREET BRIDGE	214.4	-	218.5	-
70.1	DEPOT STREET BRIDGE	216.9	219.8	222.9	218.4
70.3	BOX POND DAM	224.1	-	225.8	-
72.0	HARTFORD AVENUE BRIDGE	233.4	234.2	237.5	-
72.7	NYNH&H RAILROAD BRIDGE	235.1	236.2	238.9	-
73.1	MELLEN STREET BRIDGE	236.8	237.9	239.9	237.7
73.3	SOUTH HOWARD STREET BRIDGE	239.9	-	243.0	-
73.4	NYNH&H RAILROAD BRIDGE	239.9	-	243.0	242.6
73.9	NORTH HOWARD STREET BRIDGE	243.1	-	244.2	-
74.0	NYNH&H RAILROAD BRIDGE	243.1	-	244.2	-
74.9	CENTRAL STREET BRIDGE	248.5	249.0	249.8	247.8
75.2	POND STREET BRIDGE	253.6	-	263.3	-
75.3	MAIN STREET BRIDGE	272.4	274.6	273.7	-
75.5	CEDAR SWAMP POND DAM	273.4	-	274.1	-
76.5	DILLA STREET DAM AND BRIDGE	273.8	-	274.6	274.6
77.3	MILFORD WATERWORKS DAM	298.9	-	-	-
77.5	CEDAR STREET BRIDGE	307.6	308.9	308.6	305.7
78.2	CEDAR STREET BRIDGE	322.2	-	323.0	320.6
78.9	ECHO LAKE DAM	354.3	-	-	-

NOTES

O OBSERVED AUGUST 1955

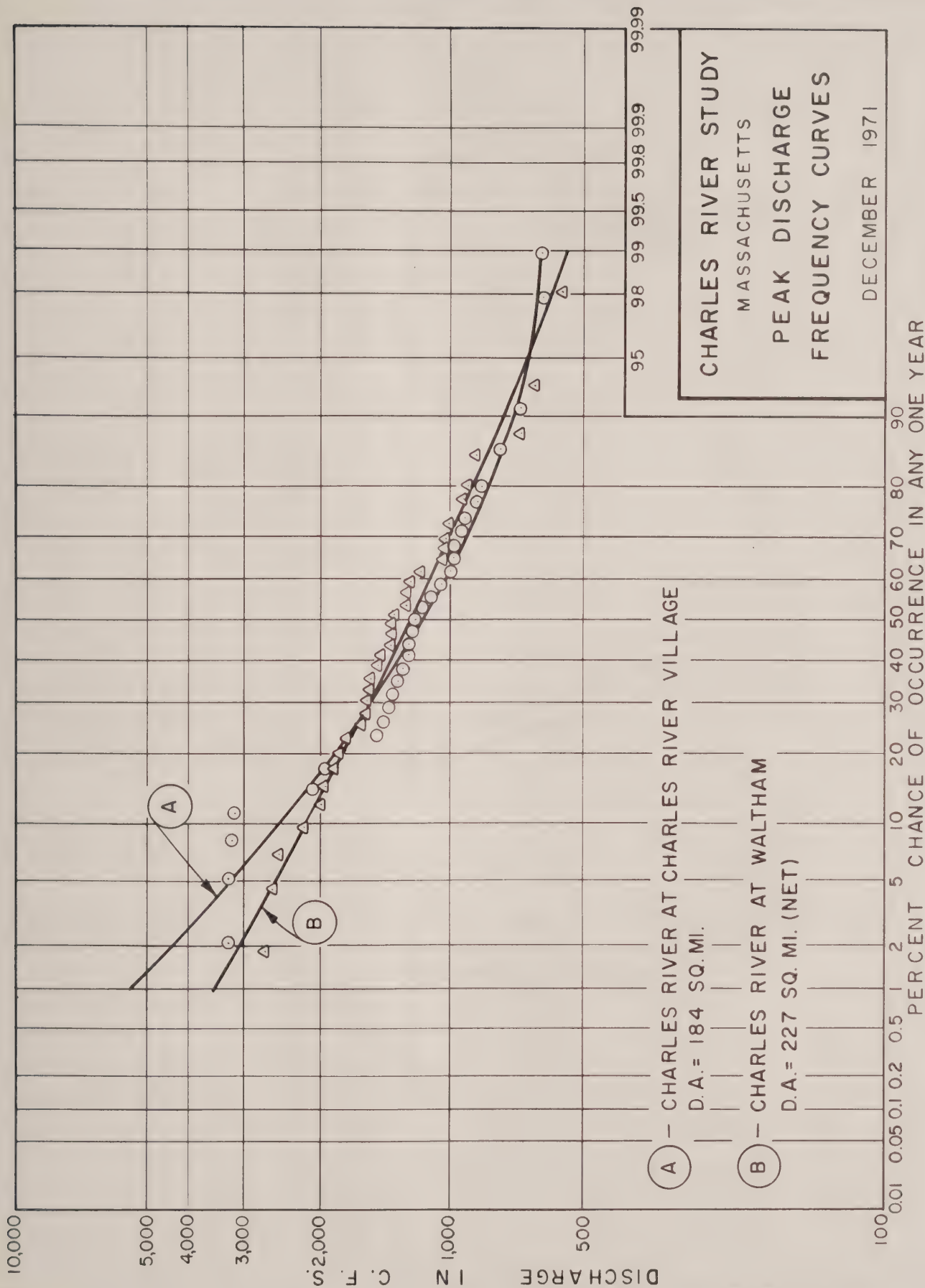
□ OBSERVED MARCH 1936

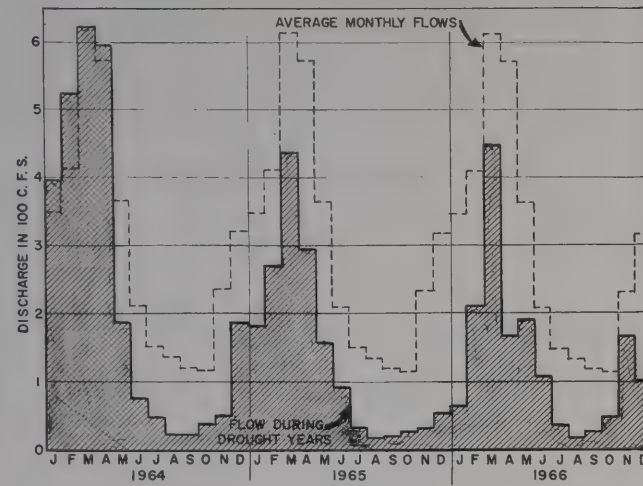
DES. BY			CHK. BY			APP. BY		
SUBMITTER			SECTION			APPROVAL RECOMMENDATION		
CHIEF			CHIEF TECH. ENGR. DIVISION			CHIEF CIVIL ENGR. DIVISION		
APPROVAL RECOMMENDATION			APPROVAL RECOMMENDATION			APPROVAL RECOMMENDATION		
DATE			DATE			DATE		
SCALE			SPEC. NO.			SHEET		

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

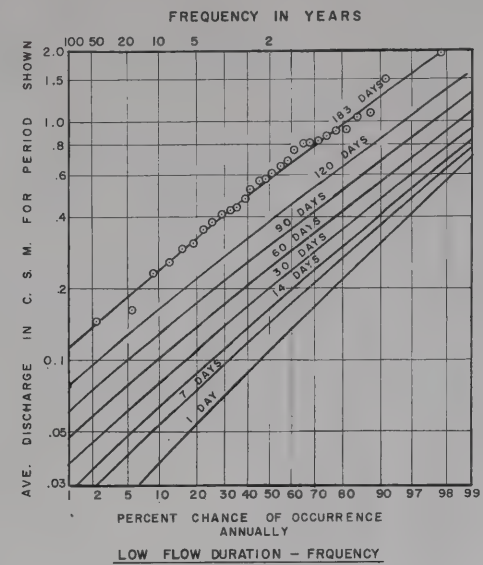
**CHARLES RIVER STUDY
FLOOD PROFILES
RIVER MILE 60 TO 80**

CHARLES RIVER, MASSACHUSETTS

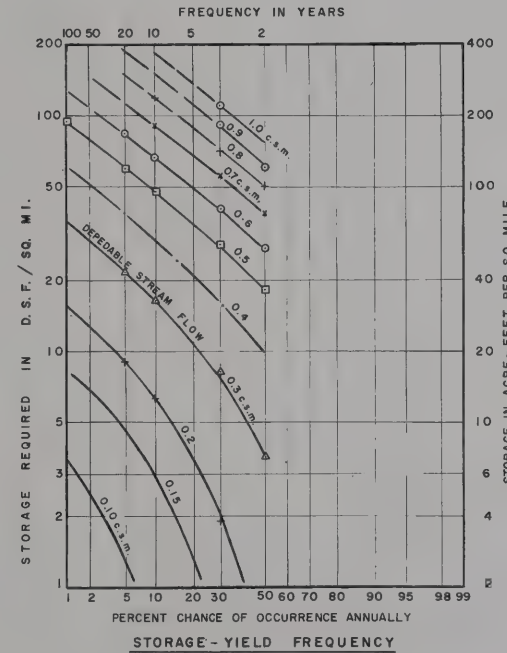
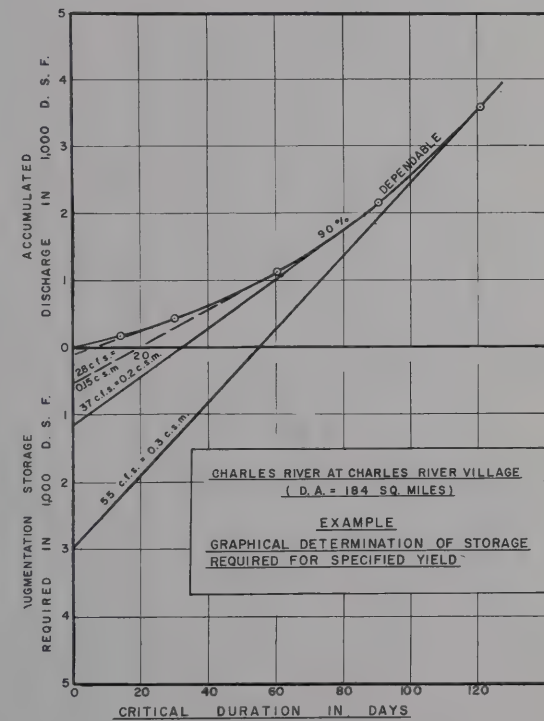




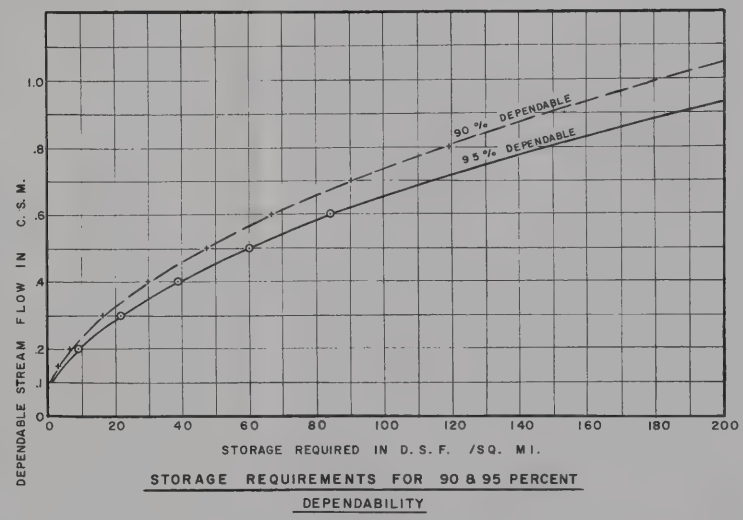
FLOW PATTERN
CHARLES RIVER AT CHARLES RIVER VILLAGE
D.A. = 184 SQ. MILES



NOTES:
C.S.M. - CUBIC FEET PER SECOND PER SQUARE MILE
D.S.F. - DAY SECOND FEET
A.F. - ACRE FEET

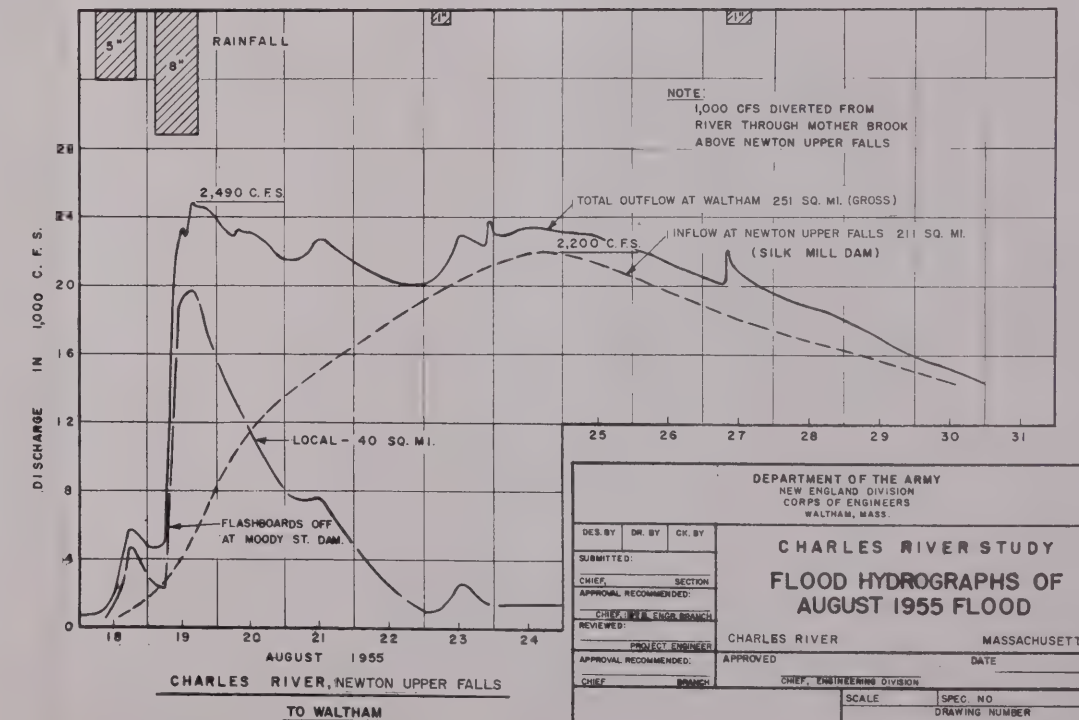
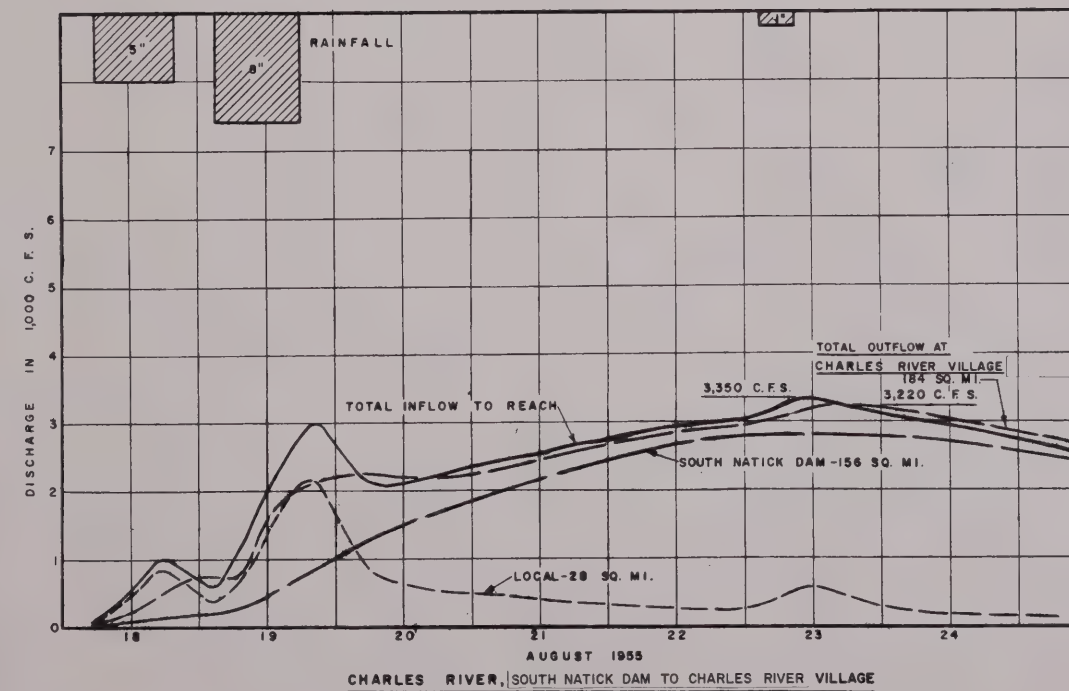
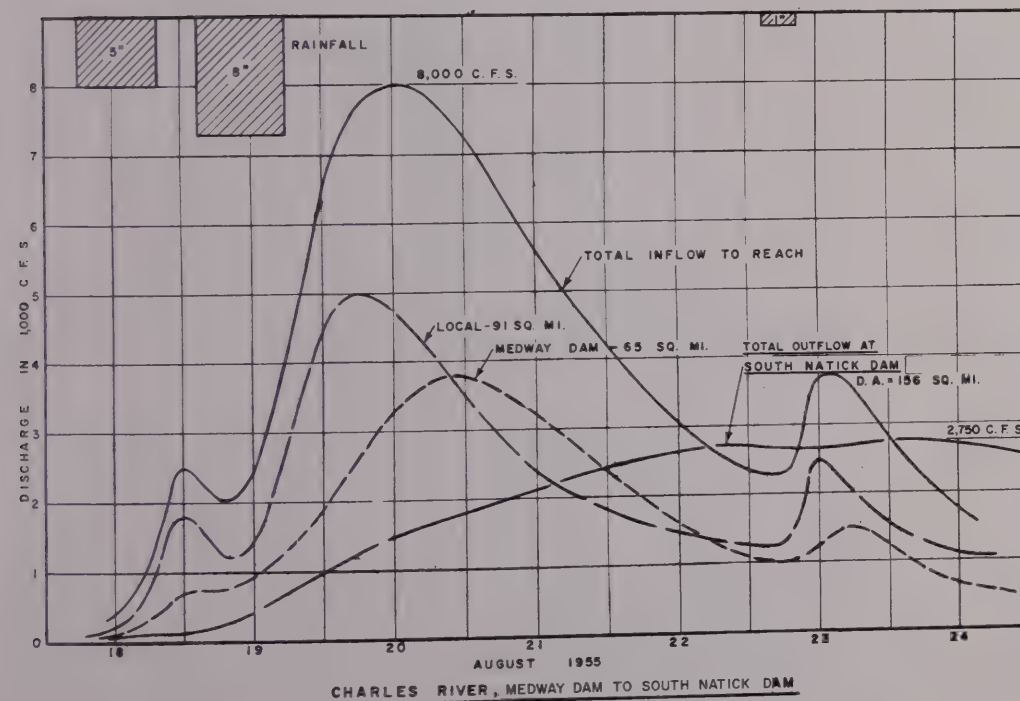
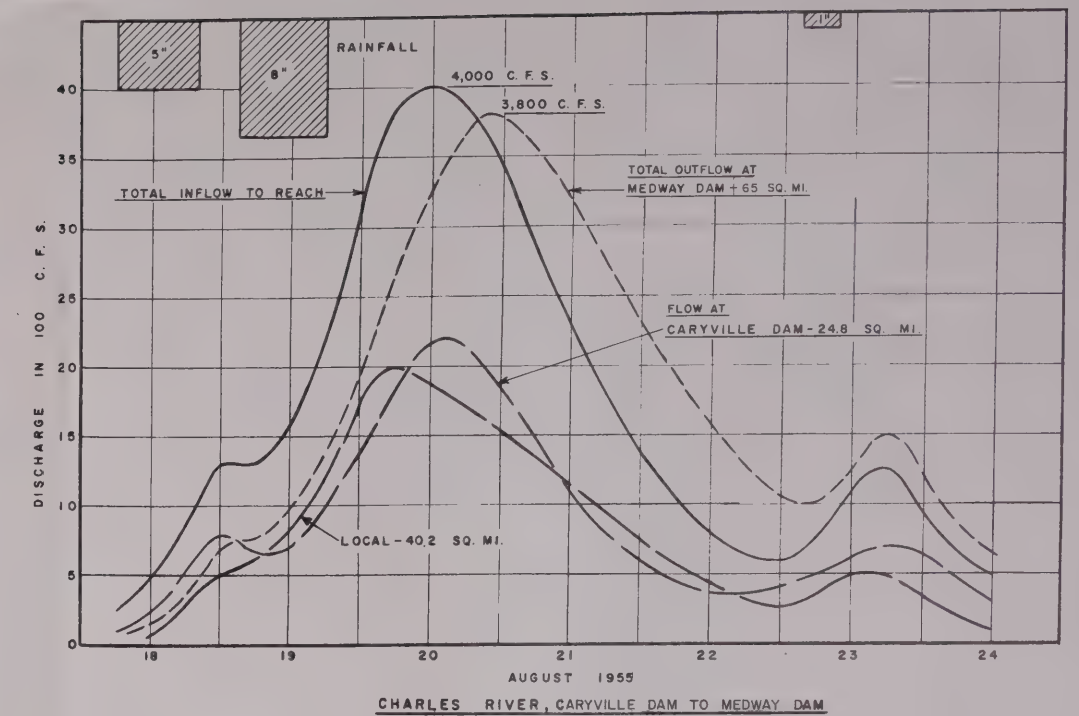
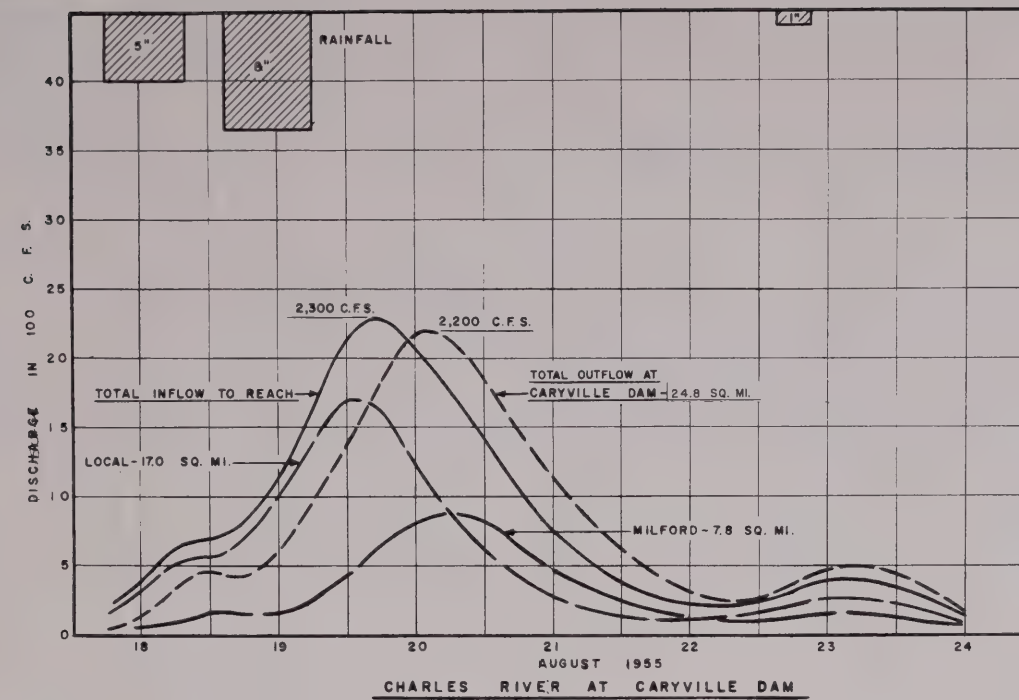
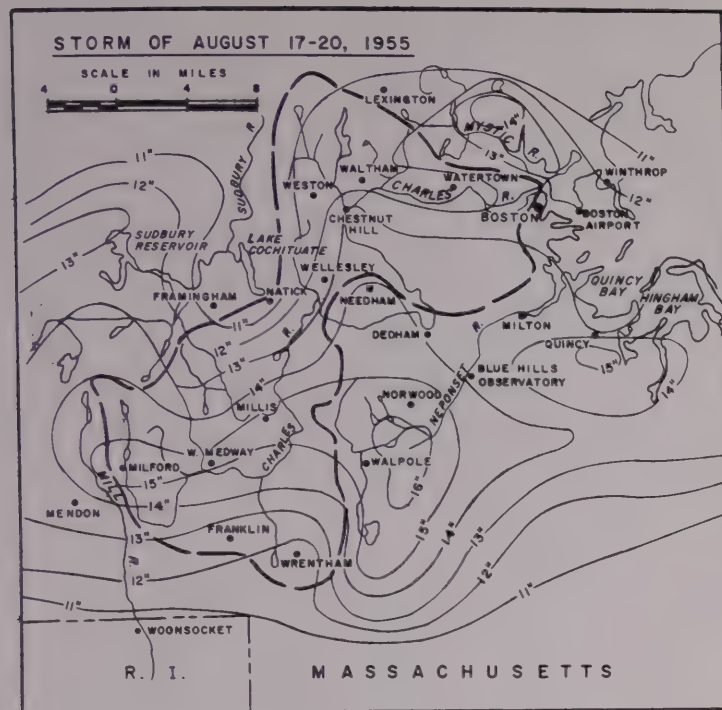


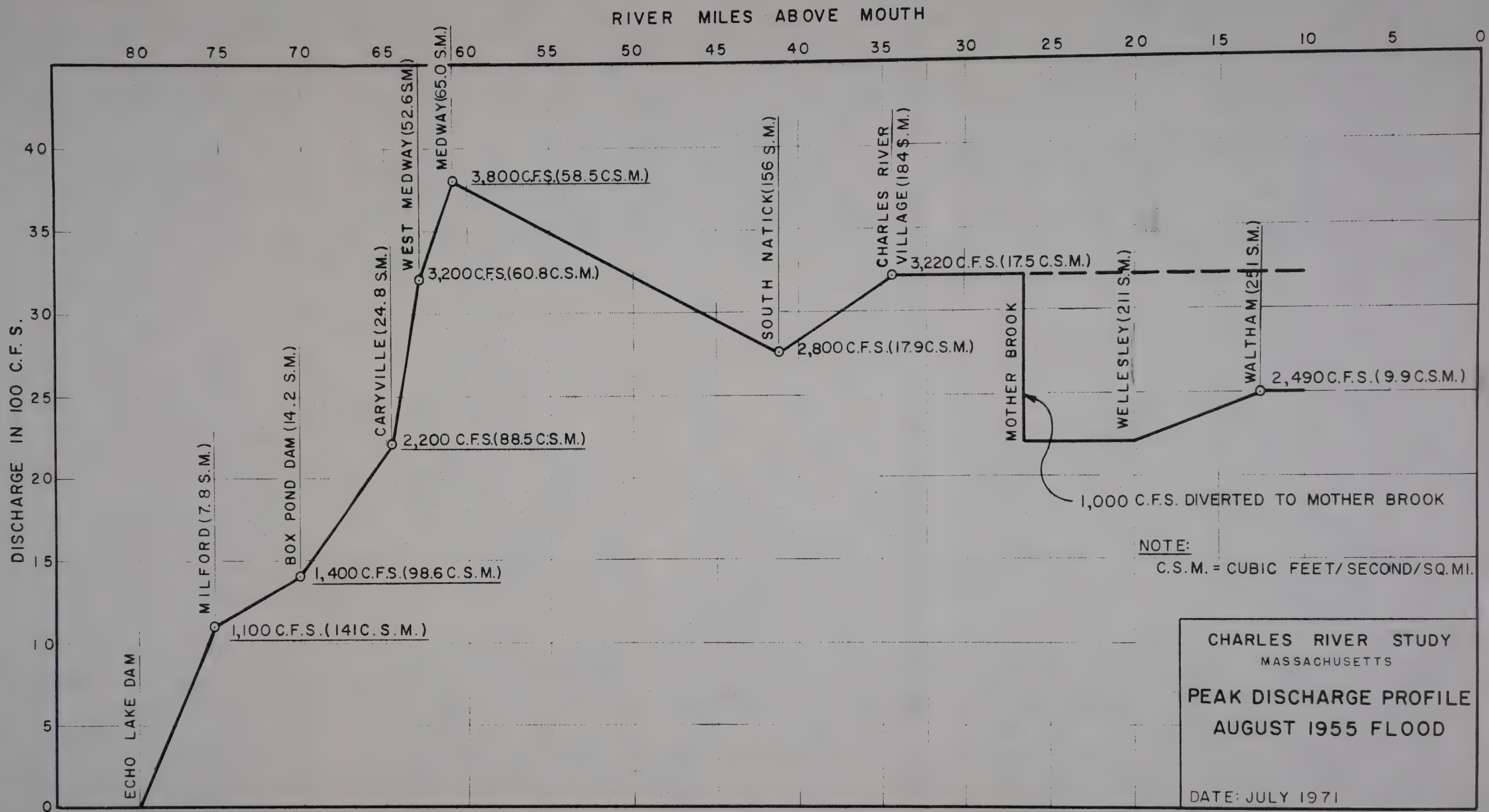
NOTE:
STORAGE REQUIREMENTS BASED ON ANNUAL
FREQUENCY ANALYSIS. PLANNING FOR LARGER
STORAGES AND YIELDS PER SQ. MILE SHOULD
INCLUDE CONSECUTIVE YEAR ANALYSIS.

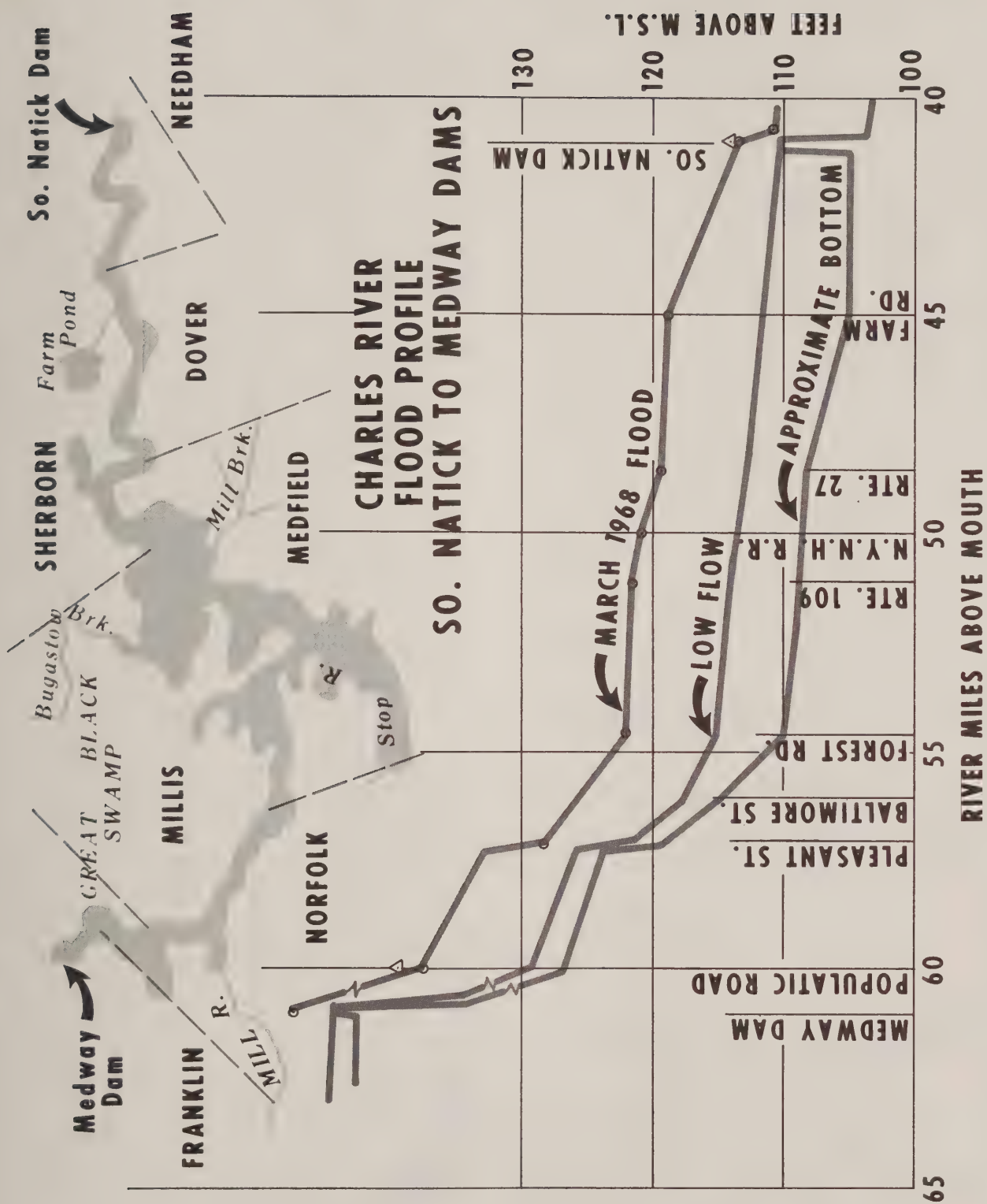


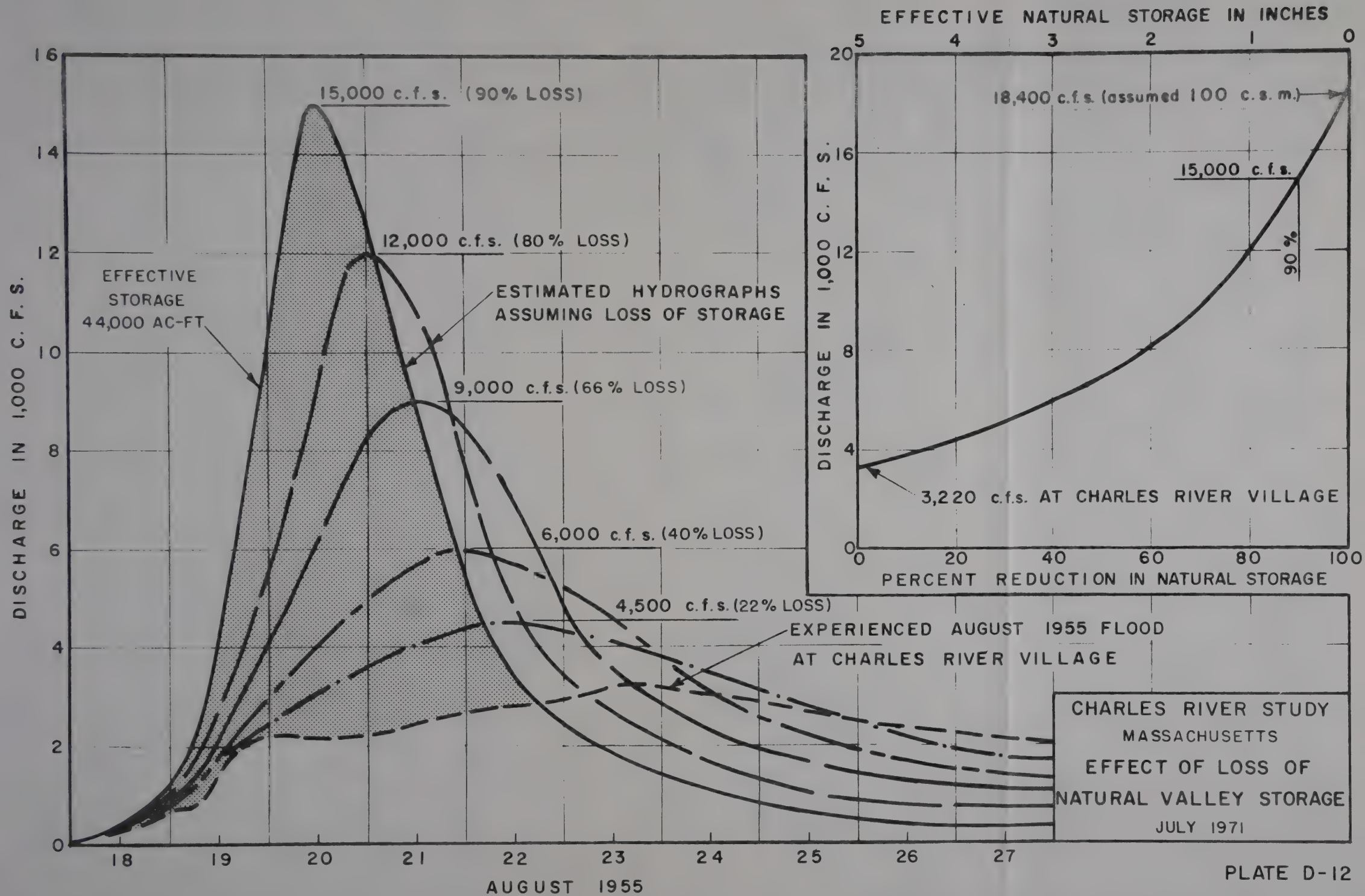
CHARLES RIVER STUDY
MASSACHUSETTS
LOW FLOW ANALYSIS

DATE: JULY 1971



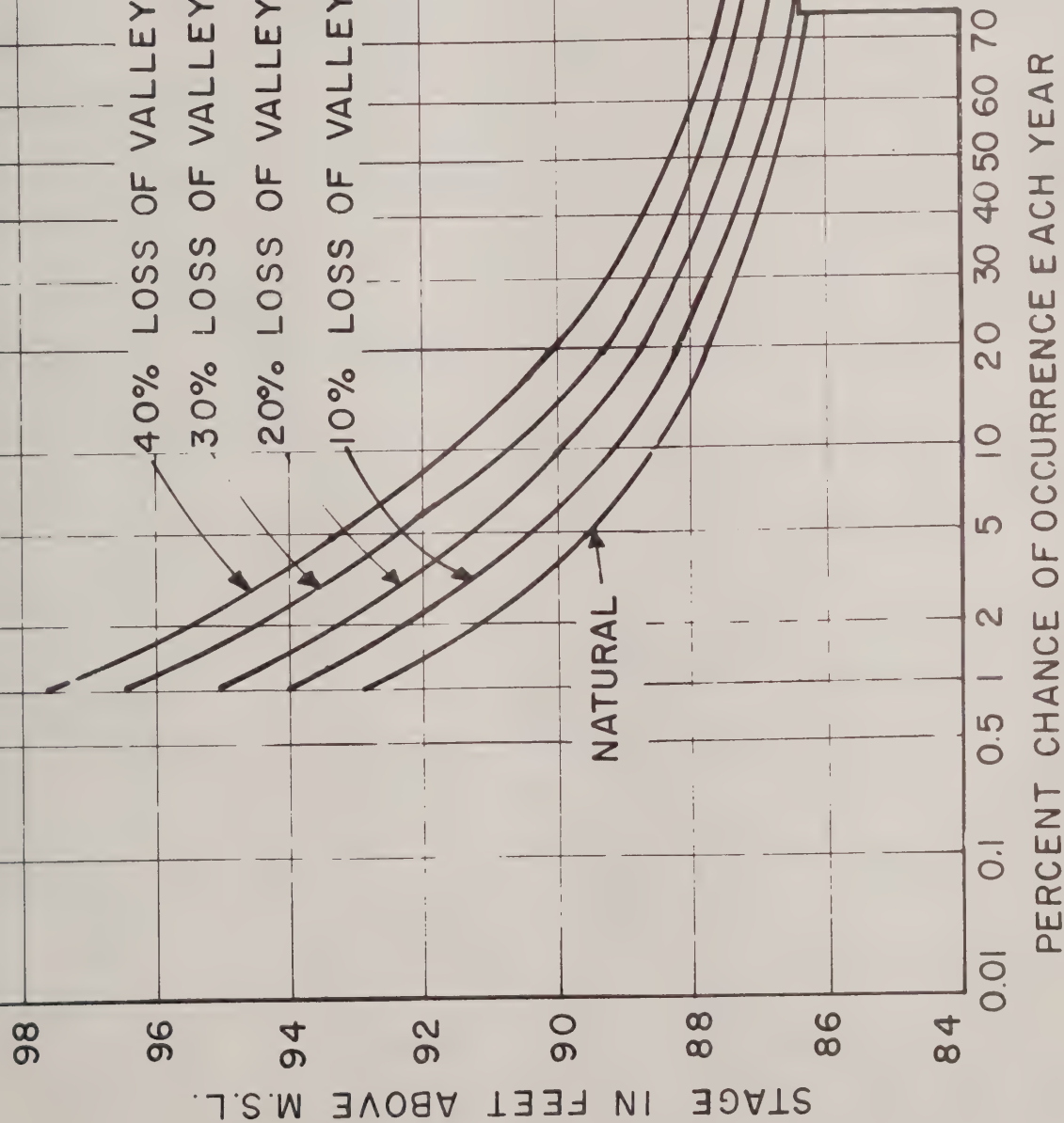






CHARLES RIVER AT MOTHER BROOK

D.A. = 200 SQ. MI.



CHARLES RIVER STUDY
MASSACHUSETTS
STAGE FREQUENCY
CURVES
DECEMBER 1971

WATER RESOURCES INVESTIGATION
CHARLES RIVER STUDY

APPENDIX E
WATER QUALITY

Prepared by
U.S. ENVIRONMENTAL PROTECTION AGENCY
Federal Water Quality Administration

New England Basins Office
240 Highland Avenue
Needham Heights, Massachusetts

DECEMBER 1971

CHARLES RIVER WATER QUALITY STUDY

APPENDIX E
OF
CHARLES RIVER STUDY

Chaired by:
Department of the Army
New England Division, Corps of Engineers
CWT 10-30

U. S. Environmental Protection Agency
Region I, Boston, Massachusetts

September, 1971

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EA	Velocity Discharge Relationships - Charles River and Tributaries
EB	General Policy and Water Quality Criteria - Commonwealth of Massachusetts
EC	Location of Water Quality Sampling Stations, 1967 and 1969 Surveys
ED	Cost Breakdown of Alternate Treatment Plant Configurations
EE	Development and Method of Application of Curves of Average Annual Reduction in Treatment Costs versus Flow Augmentation Amounts, and Flow Regimes
EF	Subsurface Disposal of Waste

1. INTRODUCTION

a. Background

A water quality investigation has been conducted at the request of the U. S. Army Corps of Engineers as one part of a comprehensive water resources study of the Charles River Watershed, Massachusetts. The objective of the water resources study is to formulate "...a plan of development which will serve as a guide to the best use, or combination of uses, of water and related land resources of the watershed to meet foreseeable short and long-term needs."

As part of the study, an interim report covering the Lower Charles River was completed by the Corps in May 1968. It recommended construction of a new dam in the Lower Charles River Basin. A discussion of water quality for that portion of the Charles River Watershed below the Moody Street Dam in Waltham (see Figure E-1) particularly as it relates to the proposed dam, is contained in that interim report.

This present report is primarily concerned with the water quality aspects of that portion of the Charles River Watershed above the Moody Street Dam in Waltham. The basic authorities for preparing this report are the Federal Water Pollution Control Act, as amended (33 U.S.C. 466 et. seq.), and a letter request dated January 27, 1966 from the Corps of Engineers.

b. Purpose and Scope

Initially, the purpose of this water quality investigation was to determine the need for and value of low flow augmentation in the Charles River Watershed. The aim was to determine if storage for water quality purposes should be included in any reservoirs that might be recommended by either the Corps of Engineers or Soil Conservation Service as part of the watershed study.

As the study progressed, it became evident there was a need for broader water quality management planning. The communities in the upper watershed have a high growth potential, the need for enhancing and protecting water uses can be expected to grow in a parallel fashion, and the choices between the several alternates that could meet water quality goals appeared to be complex. It became clear also that a major water quality management program is required to meet the goals that have already been established by the water quality standards, as well as those that may be set by desires for uses requiring higher water quality.

The scope of the study was, therefore, expanded to examine in more detail possible alternates, including alternate treatment plant arrangements, waste diversion to Boston Harbor and subsurface disposal possibilities, as well as low flow augmentation.

It should be understood that costs and technical assumptions used are generalized. They are considered suitable for comparative planning purposes, i. e., to compare one alternate with another, and to provide an order of magnitude. The final program elements, however, such as treatment processes, collection system service areas, the use of flow augmentation and operating arrangements, will necessarily be the result of more detailed studies and specific actions at the community, regional, State and Federal levels. Final decisions along these lines will be geared to an advancing technology and improving institutional arrangements. The contents of this report are not intended to provide fixed technical answers or precise costs. Instead, the intention is to provide sound information for a basinwide perspective to aid in upcoming decisions that will set water quality management trends for the foreseeable future in the watershed.

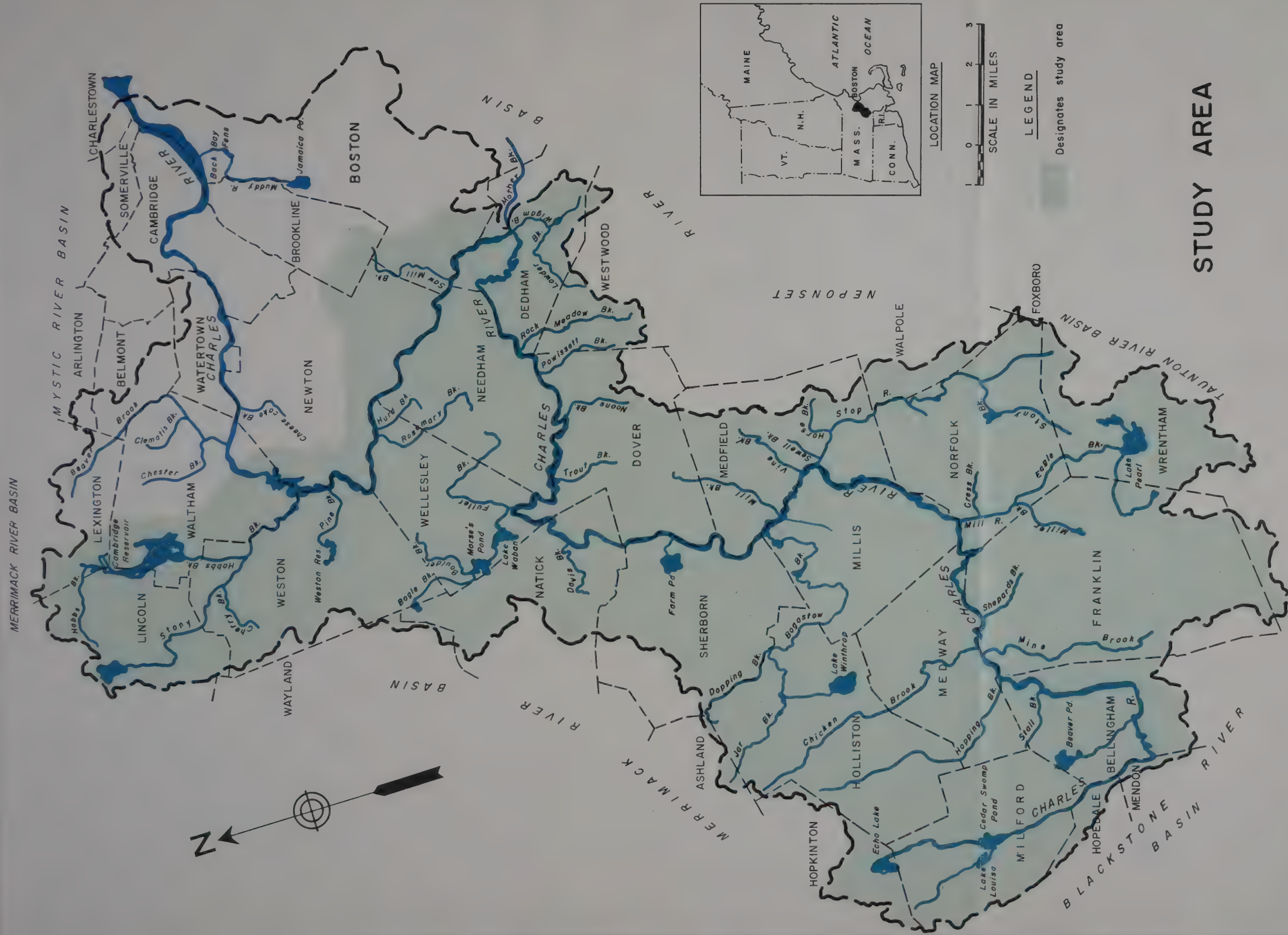


FIGURE E-1

2. DESCRIPTION OF STUDY AREA

a. Topography

The Charles River Watershed includes an area of 307 square miles in eastern Massachusetts. It is bordered on the north by the Mystic River Basin and thence in a counterclockwise direction by the Merrimack, Blackstone, Taunton and Neponset River Basins (see Figure E-2). The watershed length is 31 miles with widths ranging from five to 15 miles.

Except along the perimeter and certain interior sections, the terrain consists mainly of gently rolling hills and flat lands. Extensive wetlands are prevalent in the watershed. Elevations range from 560 feet above msl (mean sea level) along the southwesterly rim in Hopkinton to less than 10 feet above msl along the lower eight and one-half miles of the river.

The Charles River is a well-developed, meandering stream. Within the watershed's 31 miles straight-line length, the river traverses approximately 80 miles. There are 20 dams on the Charles River which affect the normal fall of 350 feet. The longest stretch of river between dams is 20.8 river miles from the Medway Dam to the South Natick Dam.

b. Climate

The Charles River Watershed has a variable climate characterized by mild pleasant summers and cold winters. The watershed lies in the path of "prevailing westerlies" and cyclonic disturbances that traverse the area from the west or southwest. It is also exposed to coastal storms, some of tropical origin, that travel up the Atlantic seaboard.

Temperature extremes in the watershed range from occasional highs in excess of 100°F (Fahrenheit) to infrequent lows below minus 20°F. The average annual temperature of the watershed is about 50°F to 51°F. Average monthly temperatures range from 72°F in July to 29°F in February in the lower watershed area and from 73°F in July to 27.5°F in January in the upper portion of the watershed.

Average annual rainfall during the year is about 41 inches in the lower Charles River area and about 44 inches in the upper portion. The area has no dry season and precipitation is distributed rather uniformly throughout the year. For example, at Boston average monthly precipitation varies from a low of 3.16 inches in June to 3.87 inches in March. The average annual snowfall in the watershed is relatively constant: about 42 inches per year.

c. Streamflow

The U. S. Geological Survey maintains gaging stations at the Charles River Village section of Needham, at Wellesley and at Waltham on the Charles River and one on Mother Brook at Dedham (see Figure E-3). Mother Brook, a canal originally constructed in 1639 for water power, now diverts about one-third of the Charles River flow at that point to the Neponset River.

The Stony Brook Sub-Watershed lying within portions of Lincoln, Lexington, Weston and Waltham, is the principal source of water for the City of Cambridge. The entire runoff from this area is diverted from the Charles River Watershed during most of each year to the City of Cambridge for water supply purposes, and subsequently disposed of through the MDC (Metropolitan District Commission) sewerage system directly to Boston Harbor. Normal flows in the Charles River are also depleted as a result of groundwater withdrawals for water supply by the towns of Dedham, Needham and Wellesley and subsequent disposal to Boston Harbor by means of the MDC sewerage system. The overall drainage area at each of the three gaging stations and effective drainage area resulting from the Mother Brook and Stony Brook diversions are shown in Table E-1.

The average annual flow measured at the Charles River Village gage which covers 31 years of record is 293 cfs (cubic feet per second) or 1.59 cfs/m (cubic feet per second per square mile). The minimum mean monthly flows that have occurred at this station are shown in Table E-2.

The Massachusetts water quality standards, which are described further in Section 3, are enforceable whenever river flows exceed the average minimum consecutive seven day flow that may be expected to occur on the average once in ten years. The average seven day low flows with a ten-year recurrence interval at Charles River Village and Waltham are 12 cfs and 4 cfs, respectively.

During September and October 1967, discharge velocity measurements were made at several locations on the Charles River on three different days by personnel of the New England Basins Office in order to estimate discharge relationships, and also to estimate the time of travel or time it takes for water to flow down the Charles River. Observed daily discharges at the Charles River Village gage on the three dates of measurement were 42 cfs, 82 cfs and 171 cfs. The discharge-drainage area relationship follows nearly a straight line function.

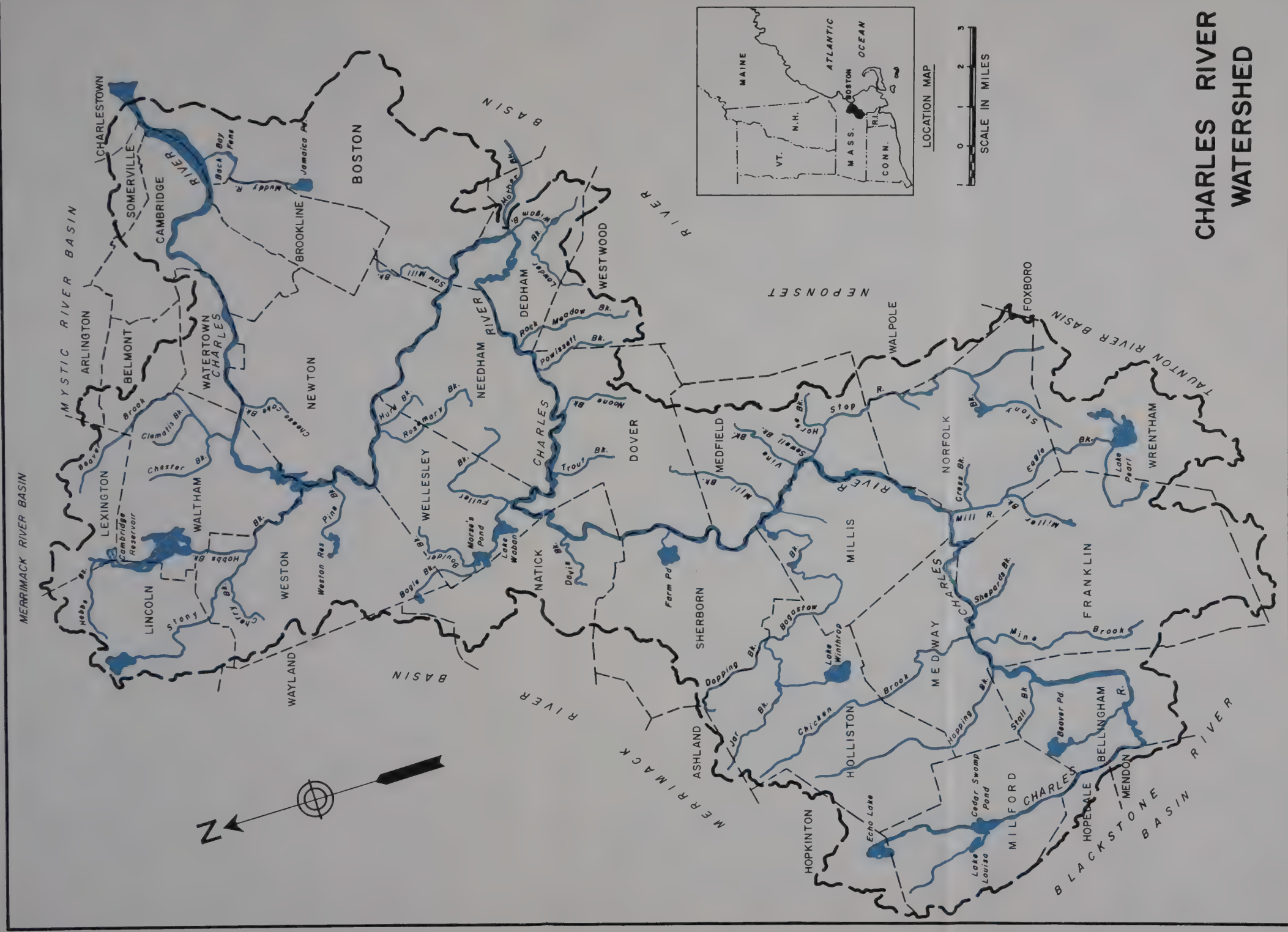


FIGURE E-2

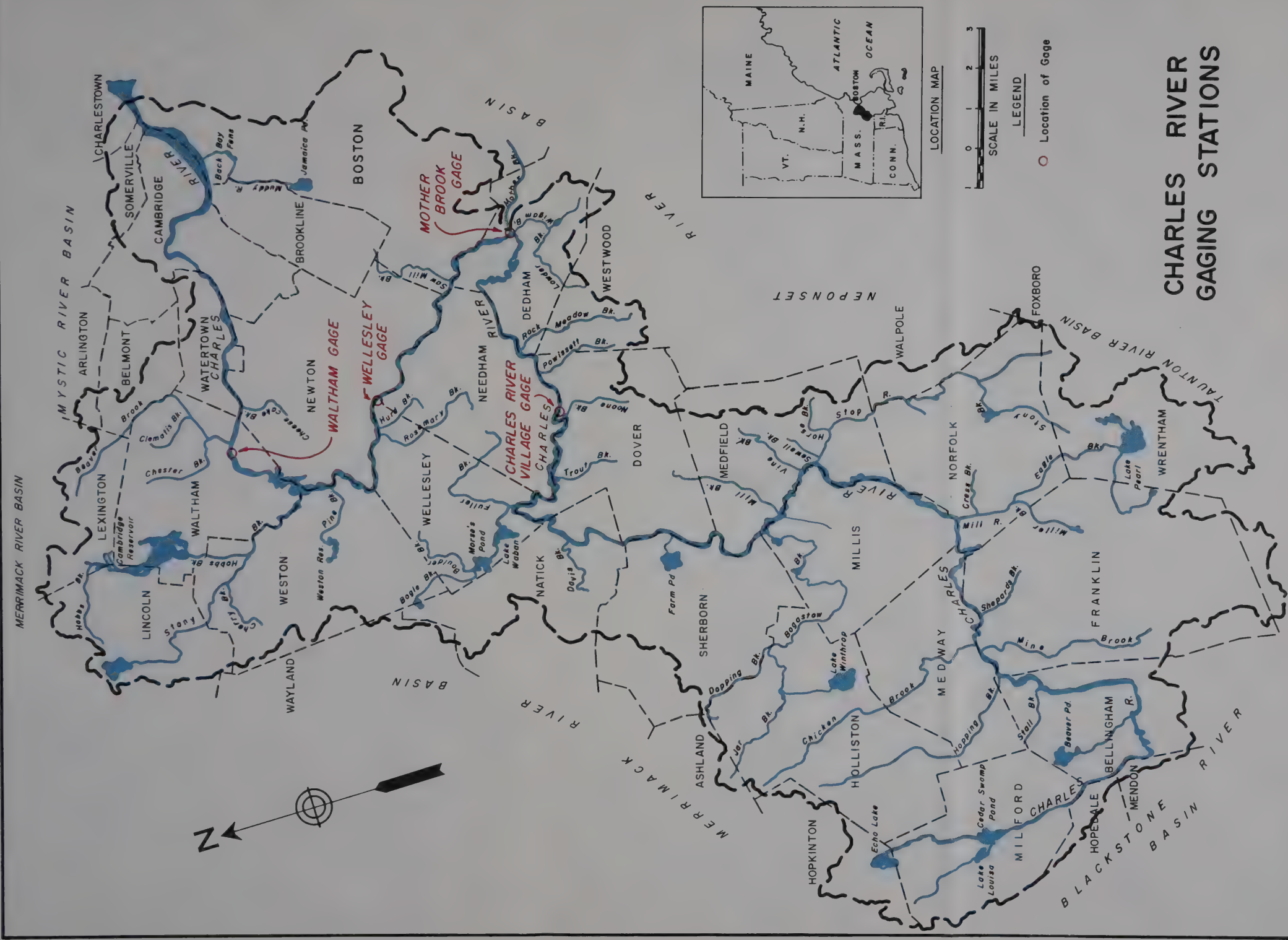


FIGURE E-3

TABLE E-1

CHARLES RIVER WATERSHED STUDY

Location and Drainage Area of Charles River
Gaging Stations

Gaging Station	River Mile	Net Drainage Area	Effective Drainage Area	Beginning of Record
		sq. mi.	sq. mi.	
Charles River Village	34.3	184.0	184.0	October 1937
Wellesley	20.0	211.3	145.3 ¹	August 1959
Waltham	12.6	249.2	159.6 ²	August 1931

1. Allowance for diversion of one-third flow of Charles River to the Neponset River through Mother Brook.
2. Includes Mother Brook Diversion and Stony Brook Diversion.

TABLE E-2

CHARLES RIVER WATERSHED STUDY

Minimum Monthly Mean Discharges Observed At
Charles River Village Gage During 31 Years of Record

Month	Minimum Monthly Mean Discharge (cfs)	Year Occurring
October	13.4	1957
November	33.1	1965
December	54.6	1965
January	65.8	1966
February	143	1944
March	304	1941
April	169	1966
May	158.0	1965
June	67.2	1957
July	19.5	1957
August	9.01	1957
September	7.78	1957

The velocities that were measured on the three dates and velocities measured by the U.S. Geological Survey at the three gaging stations served as the basis for estimating time of travel relationships of the Charles River under a range of low flow conditions. The discharge-velocity measurements were made at sections with different flow-velocity characteristics. Between the headwaters and the Moody Street Dam, the main stem was divided into 28 reaches. Four of the tributary streams were also divided into reaches. A new reach was established whenever a change in the flow characteristics occurred, such as at impoundments, at the confluence of major tributary streams, and at the location of present or estimated future waste loads. Equations in the form of " $v = aQ^b$ ", where " v " is the velocity in fps (feet per second), " Q " is the discharge in cfs, and " a " and " b " are constants, were developed for each reach. The equation for each reach and also the discharge of each reach as a function of the measured discharge at the Charles River Village Gage are shown in Attachment EA.

d. Population

Table E-3 presents the 1960 population of the 35 cities and towns that lie wholly or partially within the watershed, together with the estimated population of each town that resides within the watershed boundary.

The watershed population of 800,000 is about 15 percent of the 1960 State population of 5,150,000. The watershed includes significant portions of the most highly developed section of New England, the Boston Metropolitan area.

The population density within the Charles River Watershed varies from highly urban in the lower reaches to semi-rural in the upper reaches. The average population densities found in the Charles River Watershed communities in 1960 were as high as 22,400 persons per square mile in Somerville and 15,200 and 13,600 persons per square mile in Cambridge and Boston, respectively. At the other extreme, population densities of 110 and 185 persons per square mile occurred in Sherborn and Dover. Figure E-4 reflects the range of population densities found within the Charles River Watershed.

TABLE E-3

CHARLES RIVER WATERSHED STUDY

1960 Population of Charles River Municipalities

UPPER CHARLES			LOWER CHARLES		
Municipality	Total Population	Charles River Portion	Municipality	Total Population	Charles River Portion
Ashland	7,780	300	Arlington	49,955	3,000
Bellingham	6,775	2,600	Belmont	28,715	10,000
Foxboro	10,135	10	Boston	697,195	300,000
Franklin	10,530	9,600	Brookline	54,045	54,045
Holliston	6,220	6,200	Cambridge	107,715	65,000
Hopedale	3,985	400	Dedham	23,870	16,000
Hopkinton	4,930	300	Dover	2,845	2,400
Medfield	6,020	4,700	Lexington	27,690	3,500
Medway	5,170	5,170	Lincoln	5,615	3,400
Mendon	2,070	50	Needham	25,795	25,795
Milford	15,750	14,000	Newton	92,385	92,385
Millis	4,375	4,375	Somerville	94,695	32,000
Natick	28,830	10,000	Waltham	55,415	55,415
Norfolk	3,470	3,470	Watertown	39,090	34,000
Sherborn	1,805	1,400	Wayland	10,445	200
Walpole	14,070	1,200	Wellesley	26,070	26,070
Wrentham	6,685	2,000	Weston	8,260	7,500
			Westwood	10,355	2,900
Sub-Total	138,600	65,775	Sub-Total	1,360,155	733,610
			Total	1,498,755	799,385

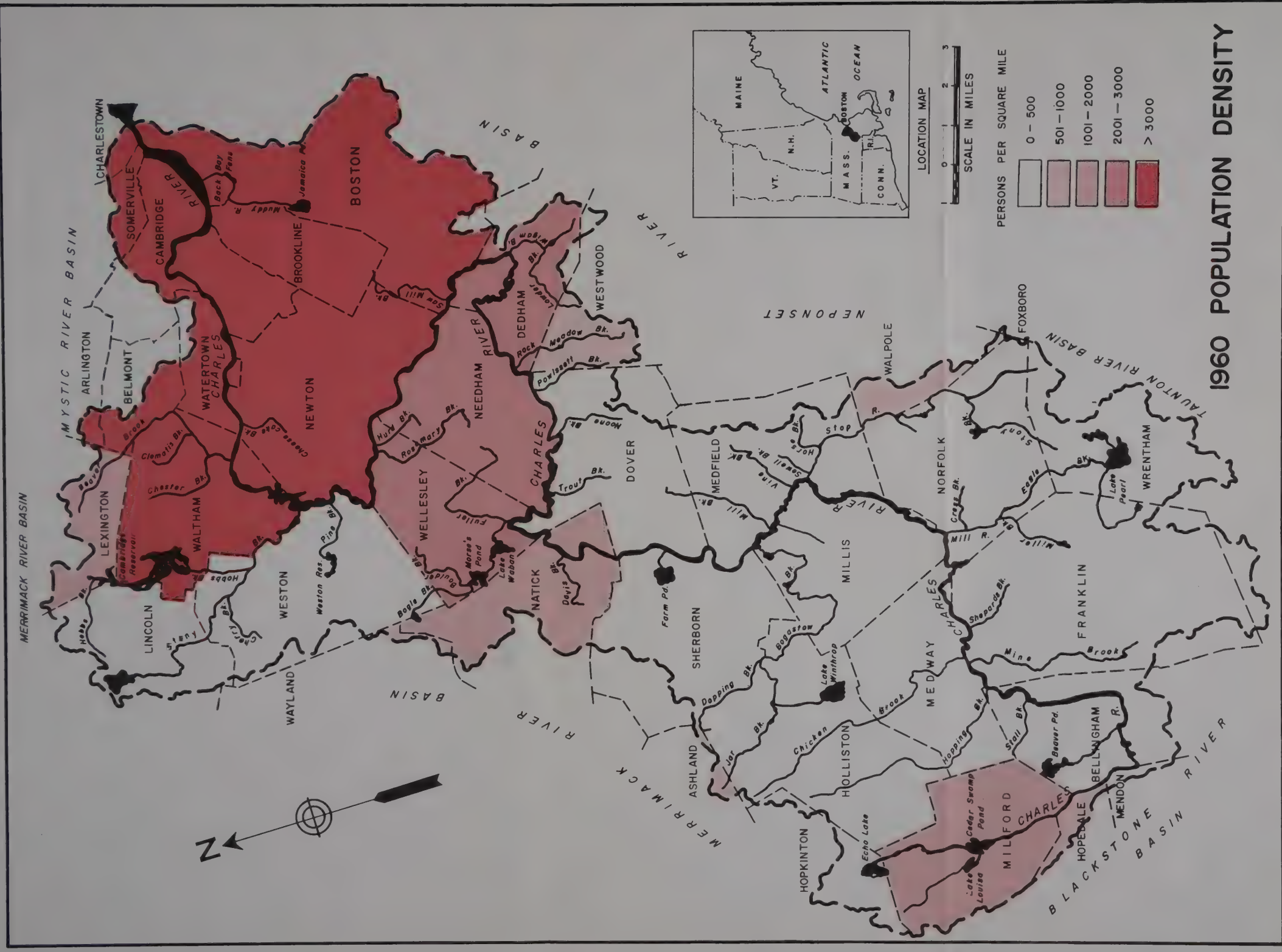


FIGURE E-4

3. PRESENT WATER QUALITY, WASTE LOAD AND WATER USE

a. Present Water Quality

(1) State Standards

In 1967 the Commonwealth of Massachusetts, after public hearings, established water quality standards for all of its streams and coastal waters. The standards for the Charles River, an intra-state stream, are administered and enforced wholly by the Commonwealth.

The standards include three basic essentials. First, they set the desired uses for each stretch of water. Second, they establish physical, chemical and biological limits, or criteria, which relate the water quality to the desired uses. Third, the standards contain a plan and schedule for the implementation and enforcement of the water quality criteria adopted. Massachusetts classifies its streams into four categories, A through D. The water quality criteria for each letter classification and general policies of the Commonwealth regarding measures for the attainment of the adopted standards are presented in Attachment EB. The standards adopted for the Charles River Watershed are shown on Table E-4 and Figure E-5.

Class A waters are of excellent quality and are suitable for water supply. These waters are usually tributary to water supply reservoirs and are prohibited for any other use. Class B waters are suitable for bathing and other water contact sports, are excellent fish and wildlife habitat and are of excellent aesthetic value. Class C waters are of good aesthetic value, are suitable for recreational boating, and are a suitable habitat for wildlife and common food and game fishes indigenous to the region, but they are not considered suitable for bathing. Class D waters are suitable for aesthetic enjoyment, power, navigation and certain industrial cooling and process uses.

(2) Water Quality Sampling Programs

Major sections of the Charles River and its tributaries are seriously affected by untreated and inadequately treated discharges of wastes from industrial, municipal and institutional sources. During the summer of 1967 EPA (Environmental Protection Agency)¹ personnel conducted a sampling program of the Charles River. Samples were collected at 17 locations, 15 on the main stem, on 13 different occasions. Various biological, chemical and physical parameters were measured. The Massachusetts Division of Water Pollution Control

1. Federal water quality activities were transferred to the Water Quality Office of the Environmental Protection Agency from the Federal Water Quality Administration by Reorganization Plan Number 3 of October 5, 1970. All work prior to that date, therefore, was performed by the Department of Interior.

TABLE E-4

CHARLES RIVER WATERSHED STUDY

Charles River Watershed Classification

Boundary	River Miles	Present Use	Anticipated Future Use	Present Condition	Classification
The Charles River from its source to Dilla Street, Milford	80.1-76.5	Water supply	Water supply	A	A
The Charles River from Dilla Street, Milford to Main Street, Milford	76.5-75.2	Bathing Fish & wildlife propagation Fishing	Same	B	B
The Charles River from Main Street, Milford to Bridge Street, Dover	75.2-44.7	Recreational boating Fish & wildlife propagation Fishing Assimilation	Same	D & C	C
The Charles River from Bridge Street, Dover to Watertown Dam, Watertown	44.7-9.8	Recreational boating Fish & wildlife propagation Fishing Assimilation	Same and bathing	D & C	B
The Charles River from Watertown Dam, Watertown to the Charles River Basin Dam in Boston	9.8-1.2	Recreational boating Fish & wildlife propagation Fishing Assimilation	Same	D & C	C
Farm Pond, Sherborn	--	Recreation	Recreation	B	B
All other streams in the Charles River Watershed unless denoted above	--	--	--	-	B

Commonwealth of Massachusetts, Water Resources Commission, Division of Water Pollution Control

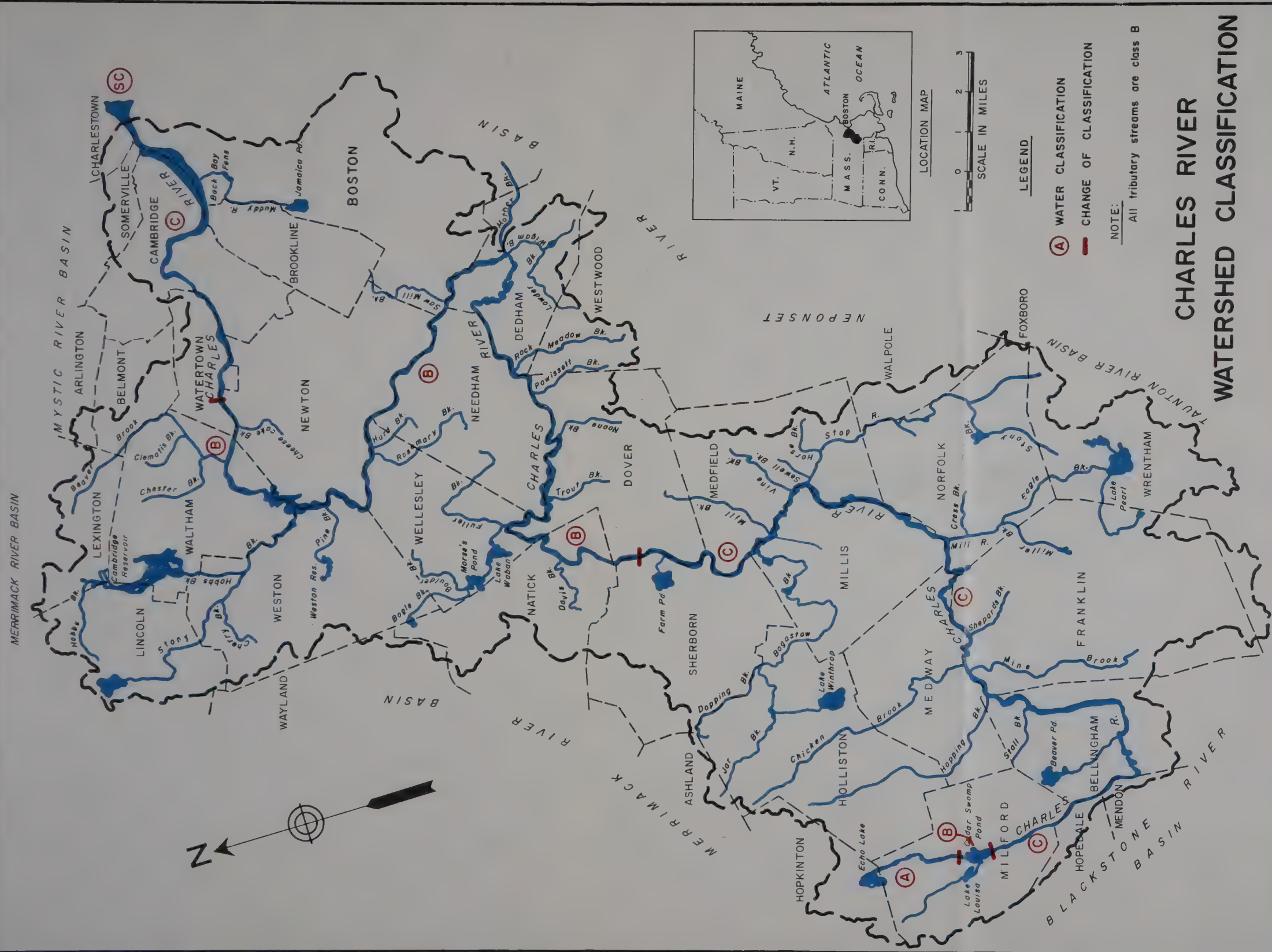


FIGURE E-5

also conducted a sampling program of the Charles River in 1967. On four different dates the Division collected samples on tributary streams and additional main stem locations to complement the EPA sampling program. During the summer and early fall of 1969, additional water quality sampling was conducted at six locations by EPA personnel under a lower flow regime than existed during the 1967 survey. (The location of each of the sampling stations is shown on Figure E-6 and described in Attachment EC.)

(3) Dissolved Oxygen and Biochemical Oxygen Demand Relationships

The concentration of dissolved oxygen in water is a significant indicator of water quality. Sewage and many industrial wastes contain organic matter which exerts an oxygen demand on the receiving waters during the process of decomposition. Oxygen is supplied to waters from the atmosphere through natural reaeration and may be contributed by algae through the process of photosynthesis. The relative strength of organic pollutants is generally measured by the amount of oxygen removed from the water in five days under controlled laboratory conditions (5 day 20°C BOD₅). Under actual conditions, the pollutants, however, continue to remove oxygen from the water over a greater time before the demand is completely satisfied. The dissolved oxygen content of a stream is progressively reduced at each successive downstream point for as long as the demand for oxygen exceeds the reaeration capabilities of the stream.

An adequate level of dissolved oxygen is necessary to maintain an environment suitable for fish and other aquatic life. Although a high level of dissolved oxygen is not necessarily required for recreation and aesthetic enjoyment, low levels can result in septic conditions and obnoxious odors. Hence, since an adequate level of dissolved oxygen is necessary for some uses and desirable for others, dissolved oxygen is one of the most suitable available indicators of water quality.

To maintain a Class B water which is capable of supporting an excellent fishery, the water quality standards require a dissolved oxygen content of not less than 75 percent saturation during at least 16 hours of any 24-hour period and not less than 5 mg/l (milligrams per liter) at any time.

For Class C waters which are suitable for a warm water fishery, the dissolved oxygen content should be at least 5 mg/l during 16 hours of any 24-hour period and never less than 3 mg/l. To maintain a Class C water for seasonal cold water fisheries, at least 5 mg/l must be present at all times.

Organic wastes are added to the Charles River near the headwaters at Milford, and again at Millis and Medfield between river miles 49.8 and 47.5. The tributaries Mine Brook and Stop River also

receive organic wastes from sources located in Franklin, and Wrentham and Norfolk, respectively.

During the summer of 1967, average dissolved oxygen concentrations in the Charles River were affected by these sources of oxygen demanding wastes, but only below Milford was the average less than 5.0 mg/l (see Figure E-7). Average dissolved oxygen concentrations of these two tributary streams which receive organic waste were significantly low as they entered the Charles River. The average dissolved oxygen concentration of Mine Brook and Stop River at their confluences with the main stem were 3.0 mg/l and 2.7 mg/l, respectively.

Summer flows in the Charles River in 1967 were above average. The mean discharge of the Charles River as recorded at the Charles River Village Gage during the 1967 sampling period was 143 cfs. The average minimum consecutive seven day low flow to be expected once in ten years, the flow that the Massachusetts standards are based upon, is only 12 cfs at Charles River Village. Had the actual flow approached this rate, much lower dissolved oxygen levels would have been found in 1967. Analyses have been made which indicate the dissolved oxygen profile at this low flow rate, and the profile is shown in Figure E-8. In 1969 the average dissolved oxygen level found below the Milford sewage treatment plant was 2.1 mg/l, significantly lower than the 1967 average. Summer flows in 1969 were also lower than 1967 summer flows.

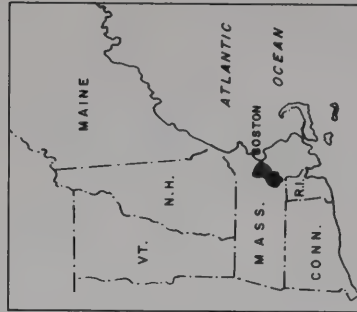
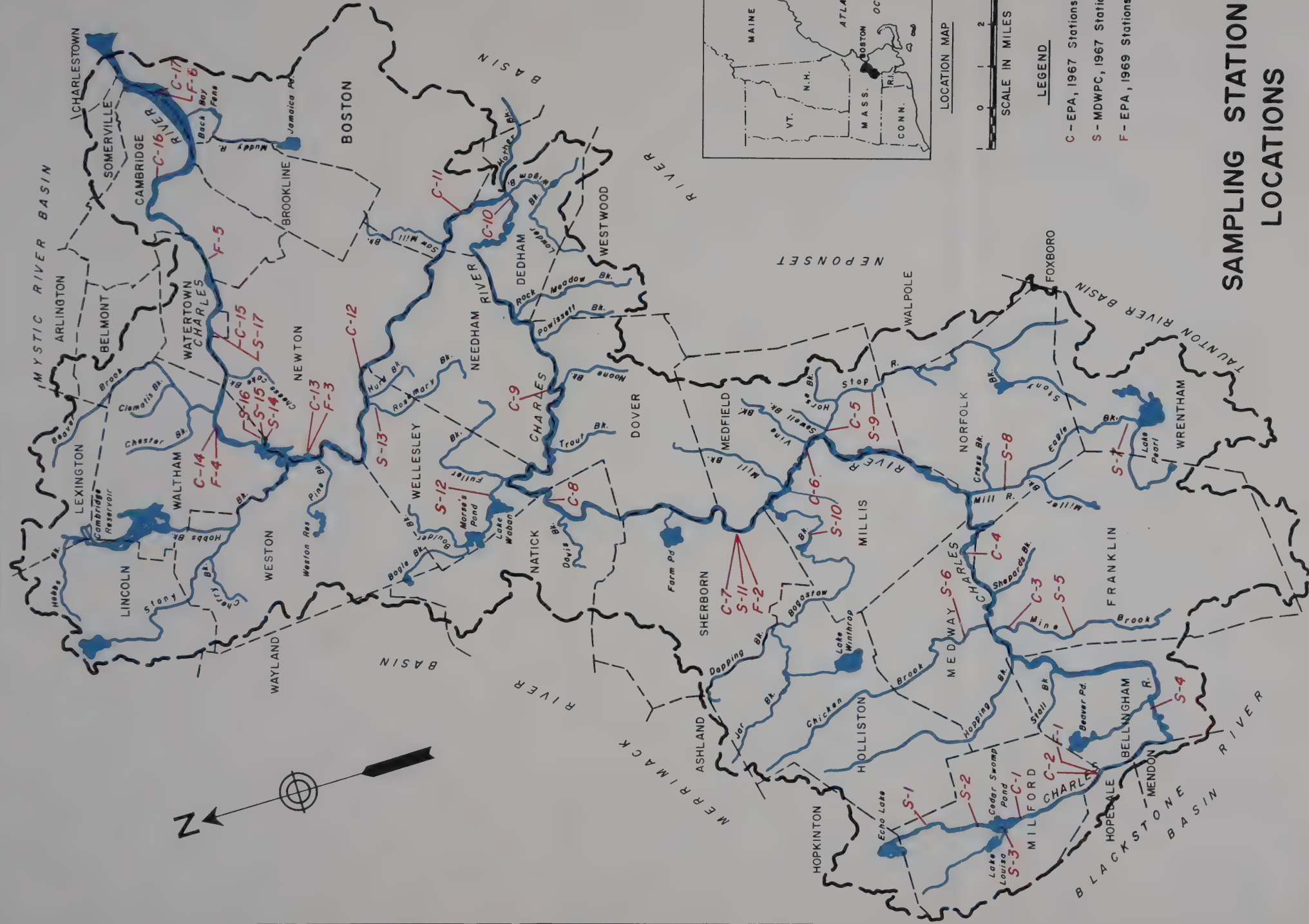
(4) Nutrients and Growth of Aquatic Plants

Algae and rooted aquatic plants require certain chemical elements for growth. Perhaps the most important of these are nitrogen and phosphorus. When they are present in sufficient amounts and other conditions for growth are favorable, undesirable and excessive growths of algae and/or rooted aquatic plants may occur. Nuisance growths tend to develop in slow moving streams and ponds and lakes.

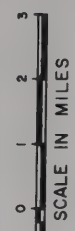
Excessive growths of algae and rooted aquatic plants can interfere with many uses of the stream. Algae blooms are aesthetically unpleasing, interfere with water supply operations, and during decay cause unpleasant odors and use up oxygen. Certain types of blue green algae are toxic to fish and waterfowl. Growth of rooted plants may severely limit recreational pursuits such as swimming, fishing and boating.

As part of the water quality standards, Massachusetts has established numerical criteria limiting the amounts of ammonia and phosphorus that may be present in the waters of the State. The concentration of total phosphate expressed as P (phosphorus) is not to exceed an average value of 0.05 mg/l for both Class B and Class C

MERRIMACK RIVER BASIN



LOCATION MAP



LEGEND

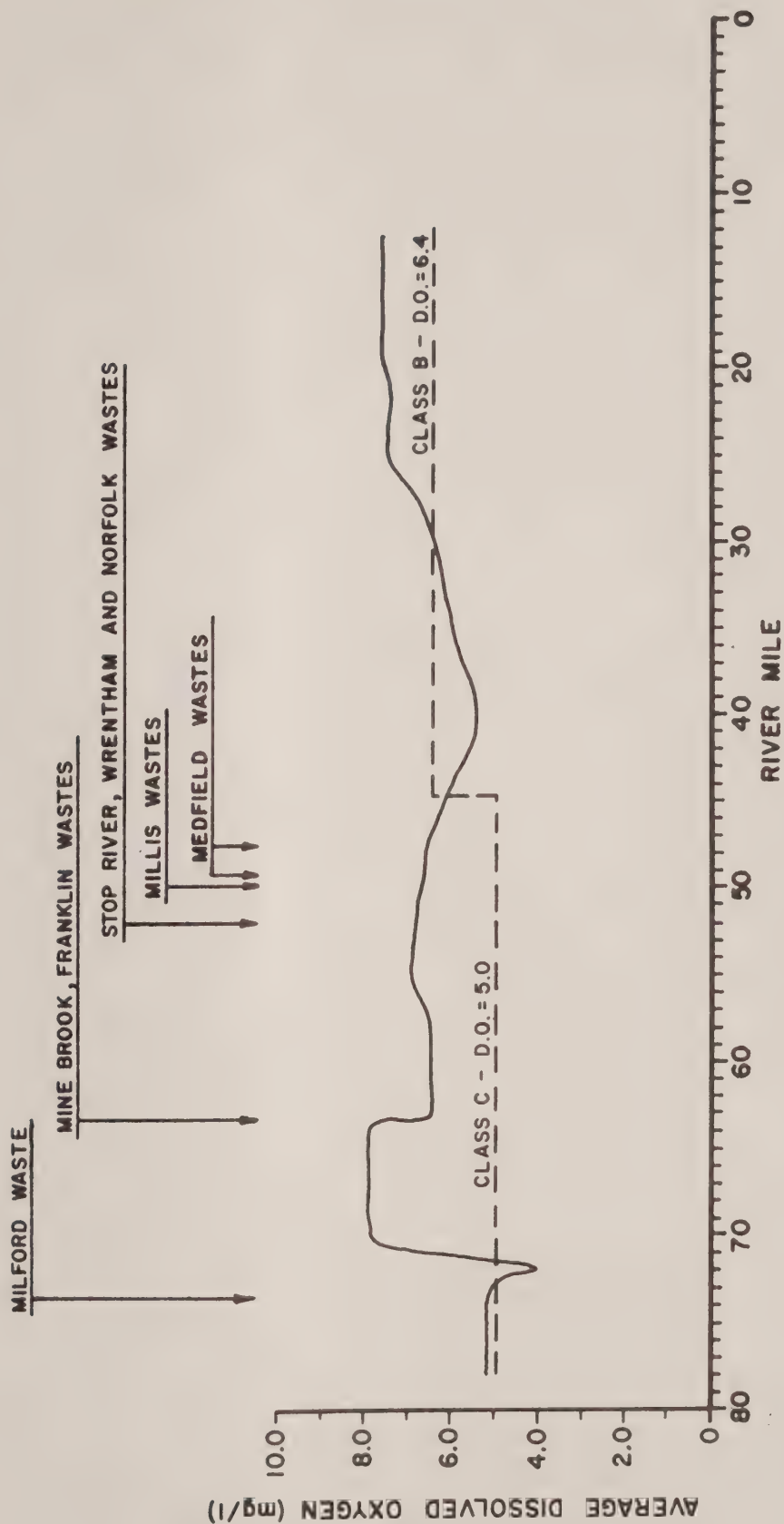
- C-EPA, 1967 Stations
- S-MDWPC, 1967 Stations
- F-EPA, 1969 Stations

SAMPLING STATION LOCATIONS

FIGURE E-6

NOTE:

1967 Waste Loads and River Flows
Average River Temperature 23° to 24°C



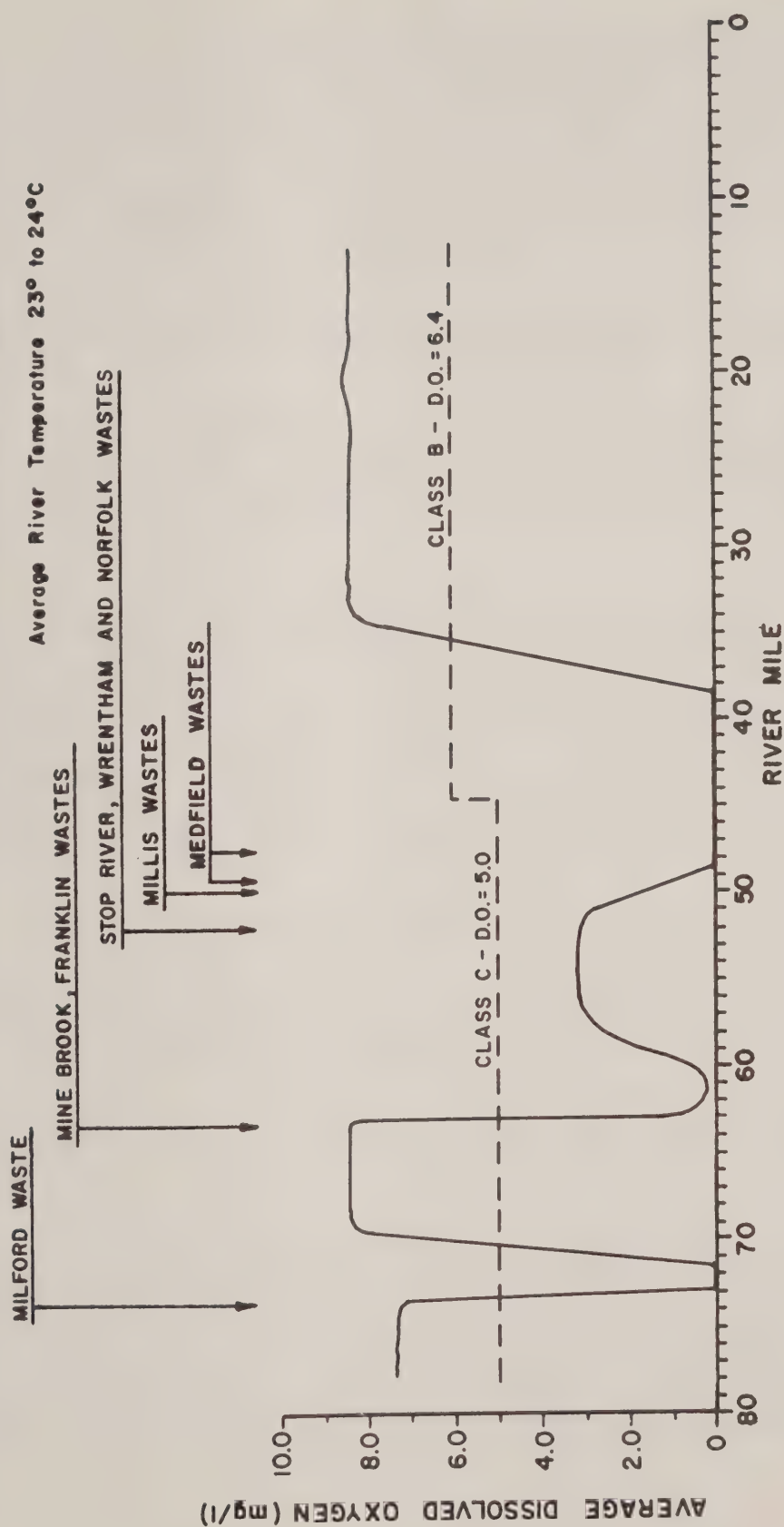
DISSOLVED OXYGEN PROFILE

NOTE:

1967 Waste Loads

River Flows Correspond to 7 Day Low Flow with a Ten Year Recurrence Interval.

Average River Temperature 23° to 24°C



DISSOLVED OXYGEN PROFILE

streams. For Class B streams, concentrations of ammonia expressed as N (nitrogen) are not to exceed an average value of 0.5 mg/l, and for Class C streams ammonia as N should not exceed 1.0 mg/l. One of the main reasons for establishing an ammonia limit is for water supply purposes. Ammonia creates a high chlorine demand to form chloramines which makes it difficult to obtain free residual chlorine necessary for disinfection. Ammonia concentrations greater than 1.0 to 2.0 mg/l are also toxic to aquatic life.

Average concentrations of total phosphate as P and ammonia as N found during the 1967 sampling program are shown on Figures E-9 and E-10.

Nutrient concentrations were extremely high below the Milford sewage treatment plant. The average total phosphate concentration as P was 3.14 mg/l, and ammonia as N averaged 3.04 mg/l. Above the treatment plant, both total phosphate as P and ammonia as N averaged 0.07 mg/l.

Mine Brook contributed significant amounts of nutrients to the Charles River. Total phosphate as P and ammonia as N concentrations averaged 1.09 mg/l and 2.93 mg/l, respectively, near the confluence. Nutrient levels in the Charles River increased substantially at the Milford treatment plant and then generally decreased as the water progressed downstream, but except at the headwaters, the average total phosphate as P was never below 0.10 mg/l and nowhere did the Charles River meet the Class B and C total phosphate criteria. Except in the vicinity of the Milford sewage treatment plant and Mine Brook, ammonia concentrations did meet the Class B standard.

Nitrates were also measured at each sampling station and the results are shown on Figure E-11. As was the case of total phosphate and ammonia, nitrate levels as N are extremely high at Milford, 4.0 mg/l. Nitrates decreased to 0.4 mg/l at Moody Street, Waltham. At all sampling stations, the inorganic nitrogen concentration (nitrates plus ammonia) was greater than 0.5 mg/l.

Concentrations of nutrients found in 1969 were slightly higher than those found during the 1967 survey because of the lower river flows in 1969.

The observed concentrations of nutrients in combination with other factors such as light intensity, turbidity and temperature were sufficient to produce growths of aquatic plants. In the upper reaches of the Charles River below the Milford treatment plant, dense growths of aquatic plants were prevalent. Dense growths were also found in Mine Brook and downstream reaches of the Charles River to Medway. Below Medway rooted aquatic plants were not prevalent, except in the ponded areas near Route 30 in Newton.

Concentrations of phytoplankton found in the Charles River are shown on Figure E-12. Generally, where extensive growths of rooted aquatic plants were present, such as at Milford and Mine Brook, concentrations of phytoplankton were low. Phytoplankton concentrations increased as the river flow progressed downstream and reached a peak of 19,800 cells/ml near the Moody Street Dam in Waltham. Waters with concentrations of phytoplankton exceeding 1,000 to 2,000 cells/ml are considered overly enriched.

Phytoplankton and aquatic plants, through the process of photosynthesis, utilize the sun's rays acting on chlorophyll to synthesize living substance from carbon dioxide and water. The end products of photosynthesis are simple sugars known as carbohydrates and free molecular oxygen which are released to the water. Respiration is another basic life process. In the respiration process, simple sugars are oxidized by drawing dissolved oxygen from the water to produce energy. Respiration continues constantly, while photosynthesis only occurs in the presence of sufficient sunlight.

During a sunny day, photosynthesis proceeds at a more rapid rate than respiration, and the dissolved oxygen content of a stream will increase, while in the absence of light, photosynthesis stops, and the dissolved oxygen content decreases through respiration. Generally, over a season there is a net production of dissolved oxygen. Where there are excessive algal growths in a stream, oxygen levels may be severely depleted at night or on cloudy days to such an extent that higher forms of life are damaged.

During the summer of 1969 dissolved oxygen and temperature monitors were placed at two locations on the Charles River to estimate the diurnal fluctuations in the stream. These locations were at the Commonwealth Avenue Bridge in Newton (river mile 15.4) and the Needham Street Bridge in Newton (river mile 21.2). This section of the Charles River had high concentrations of phytoplankton.

At the Commonwealth Avenue Bridge, ten full days of record were obtained between August 15 and 24. The daily variation in dissolved oxygen was between 1.6 and 2.5 mg/l with, except for one day, at least 11.6 hours of sunshine. Figure E-13 shows a typical daily fluctuation at this location. Dissolved oxygen concentrations were never below 6.0 mg/l at this station.

Five days of record were obtained at the Needham Street Bridge (August 15 through 19). Daily changes in dissolved oxygen at this location varied from 3.0 mg/l to 4.6 mg/l. A typical daily dissolved oxygen profile is shown in Figure E-14. The minimum dissolved oxygen concentration recorded was 7.8 mg/l. Although minimum dissolved oxygen levels were always above 6 mg/l, daily fluctuations at times were substantial.

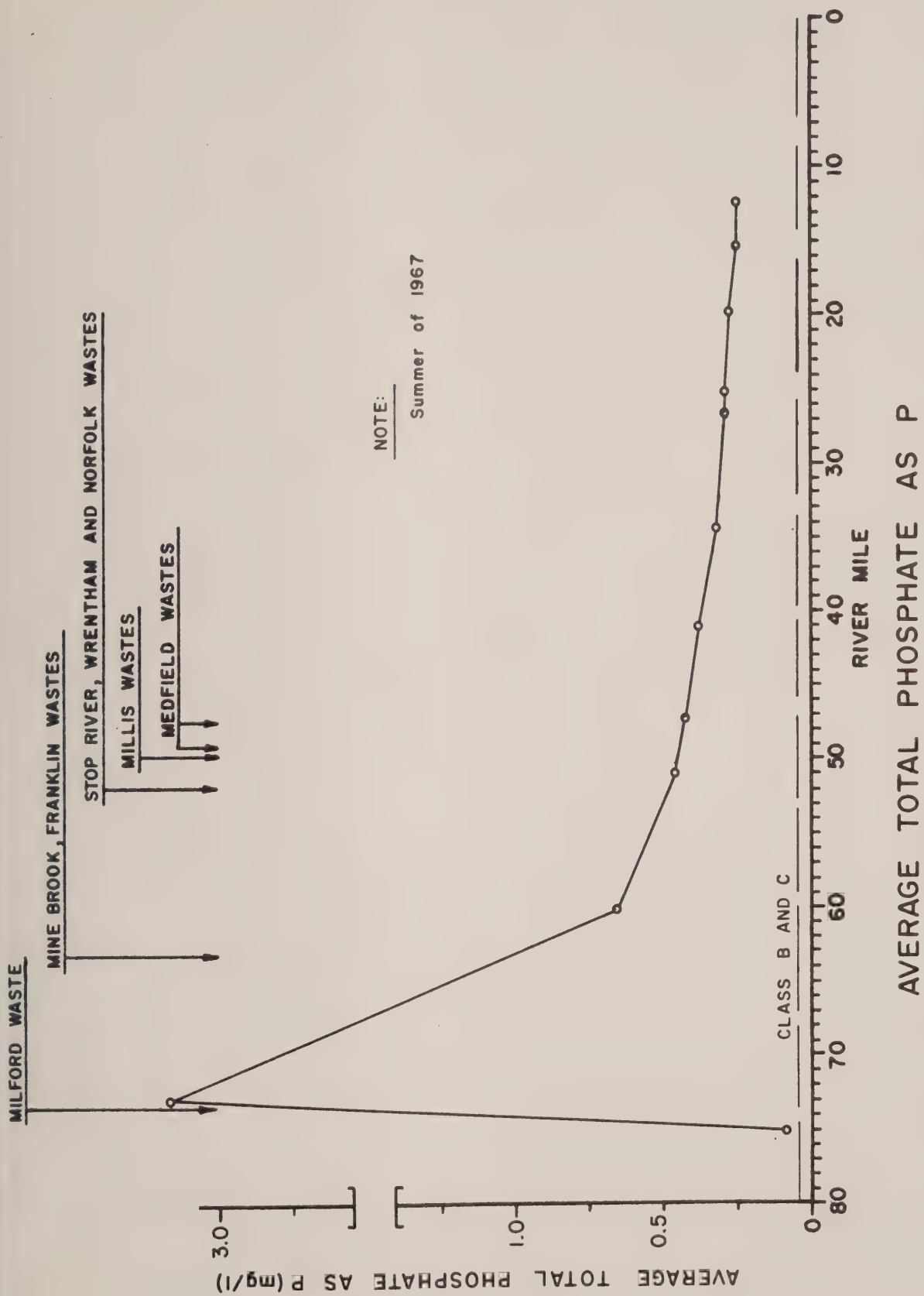
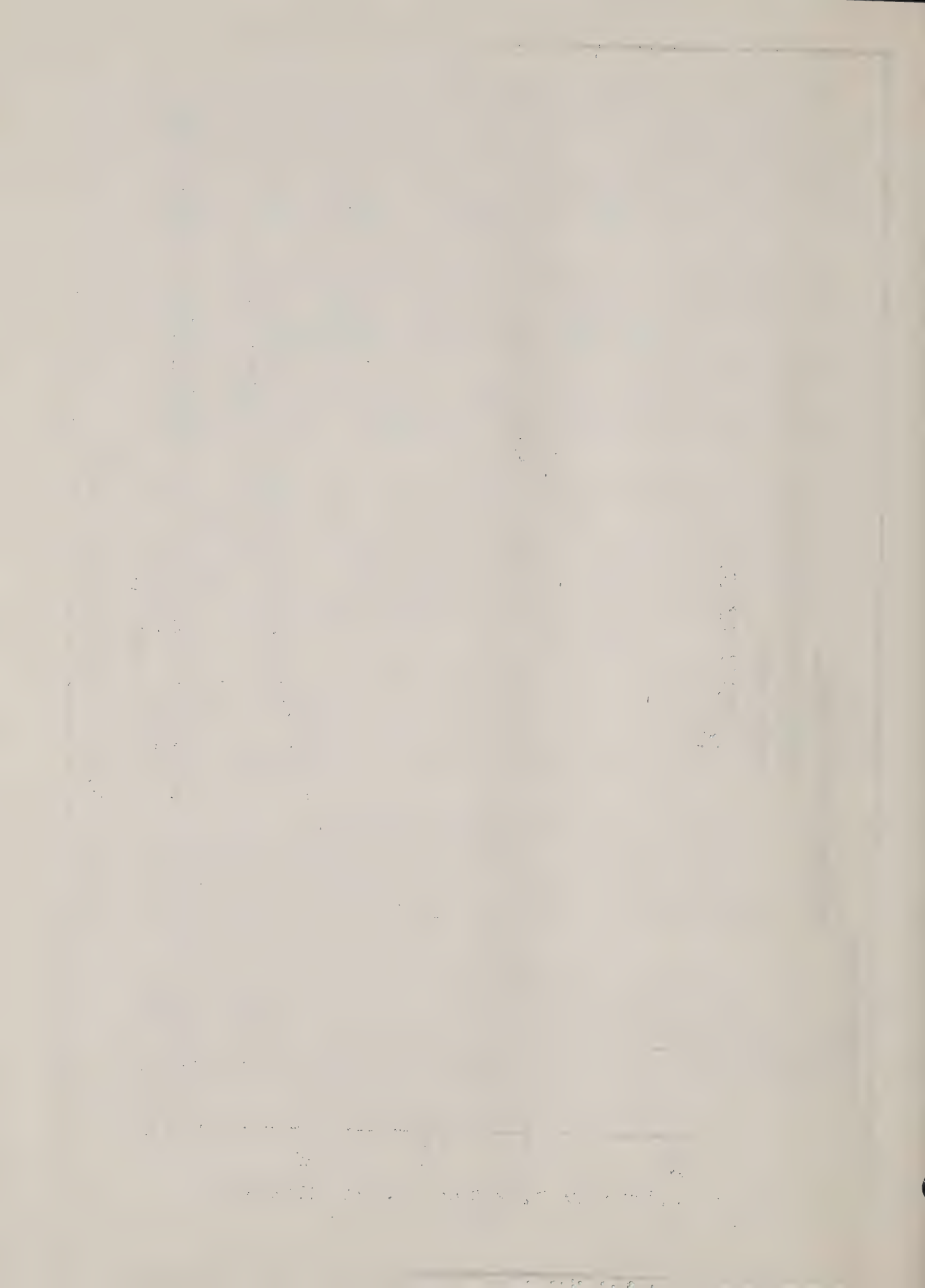


FIGURE F-9



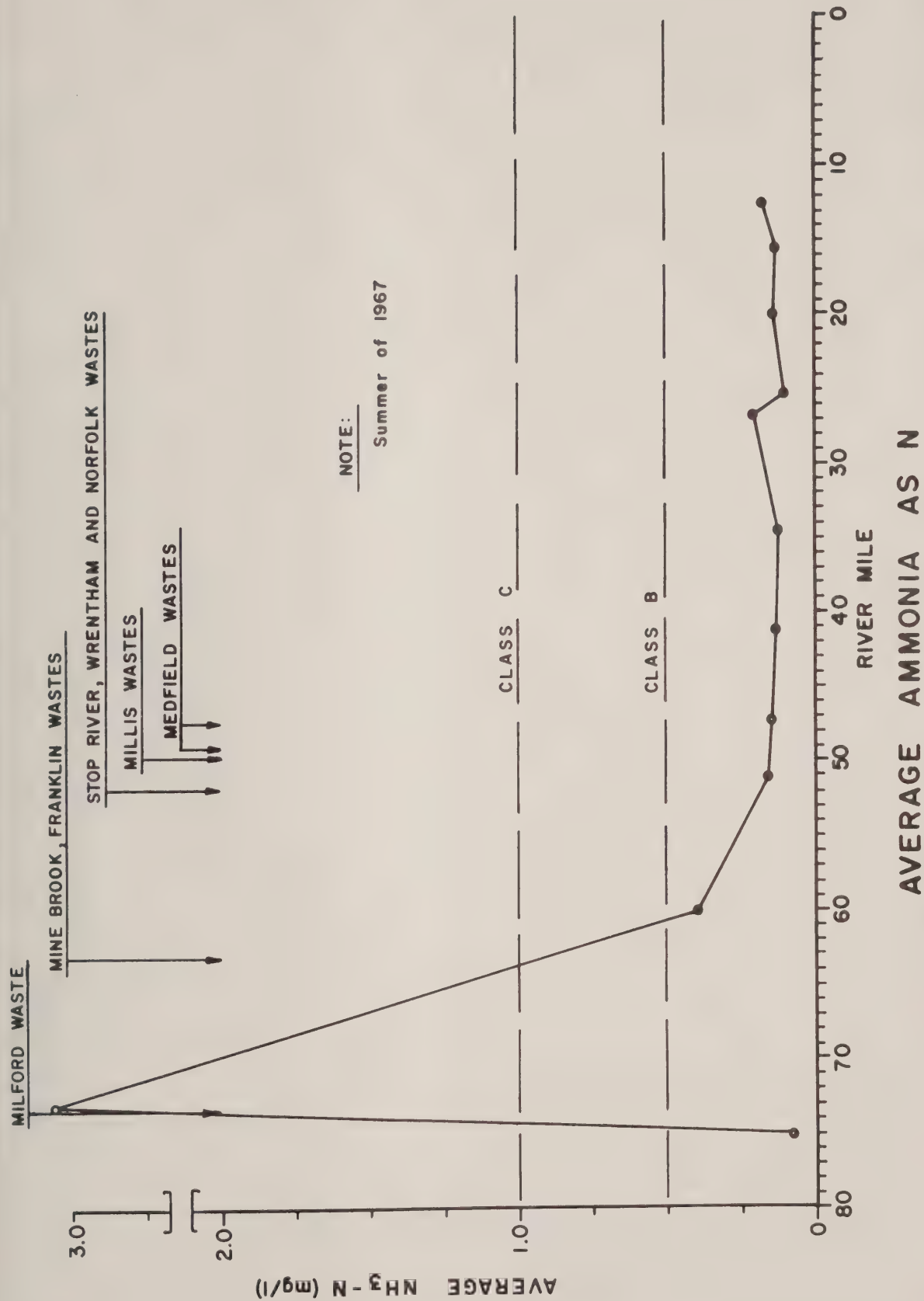


FIGURE E-10

MILFORD WASTE

MINE BROOK, FRANKLIN WASTES

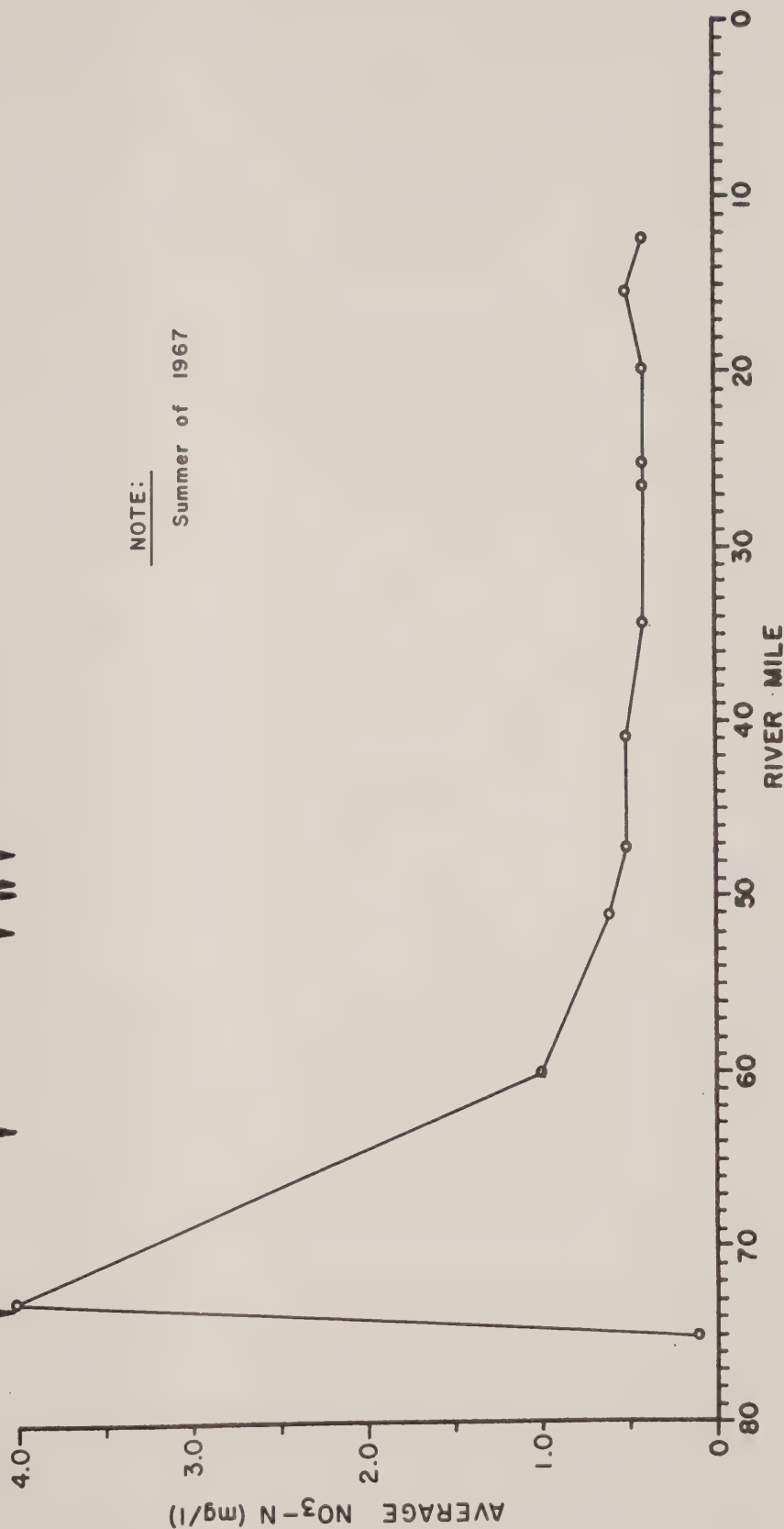
STOP RIVER, WRENTHAM AND NORFOLK WASTES

MILLIS WASTES

MEDFIELD WASTES

NOTE:

Summer of 1967



AVERAGE NITRATE AS N

FIGURE E-11

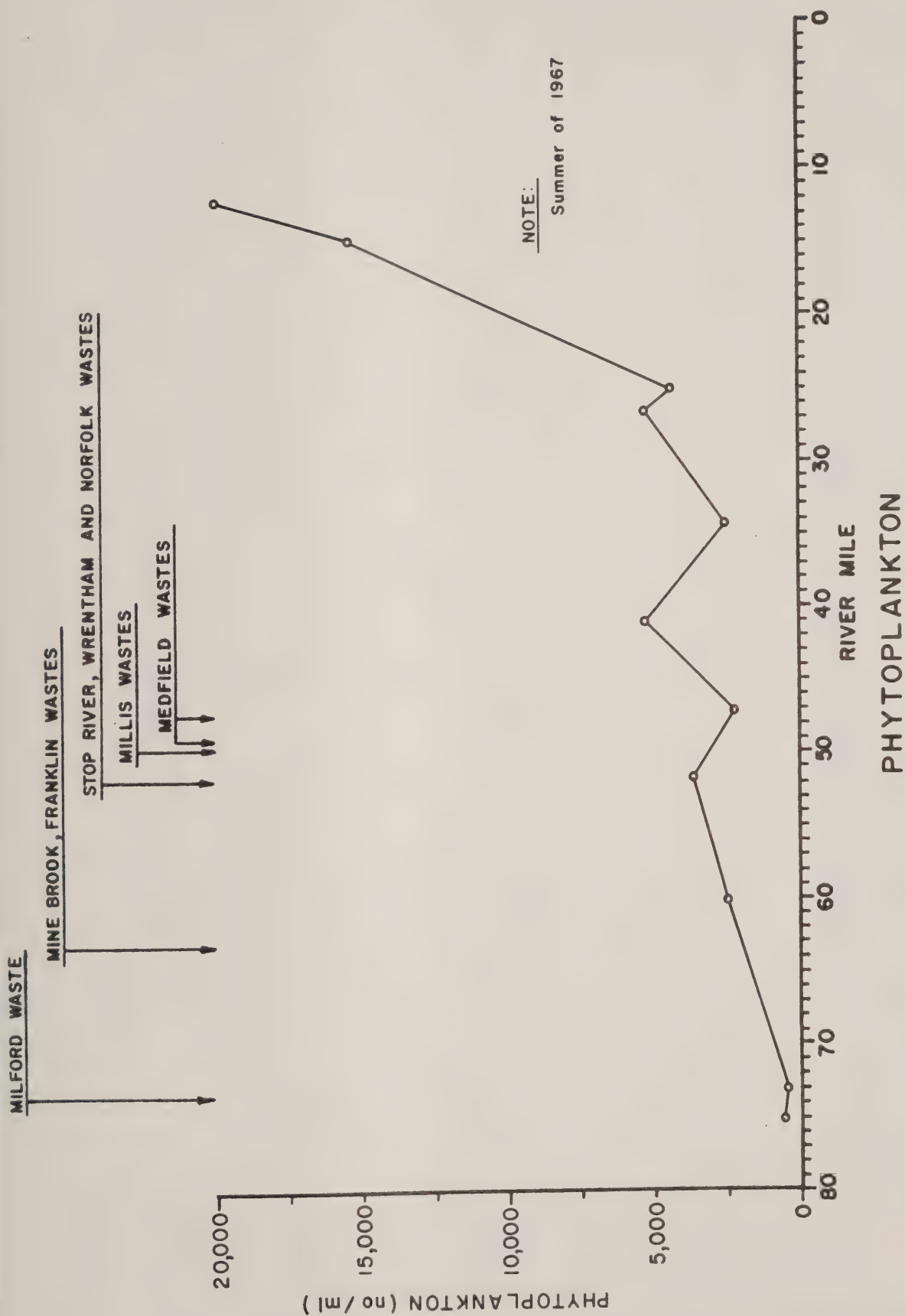
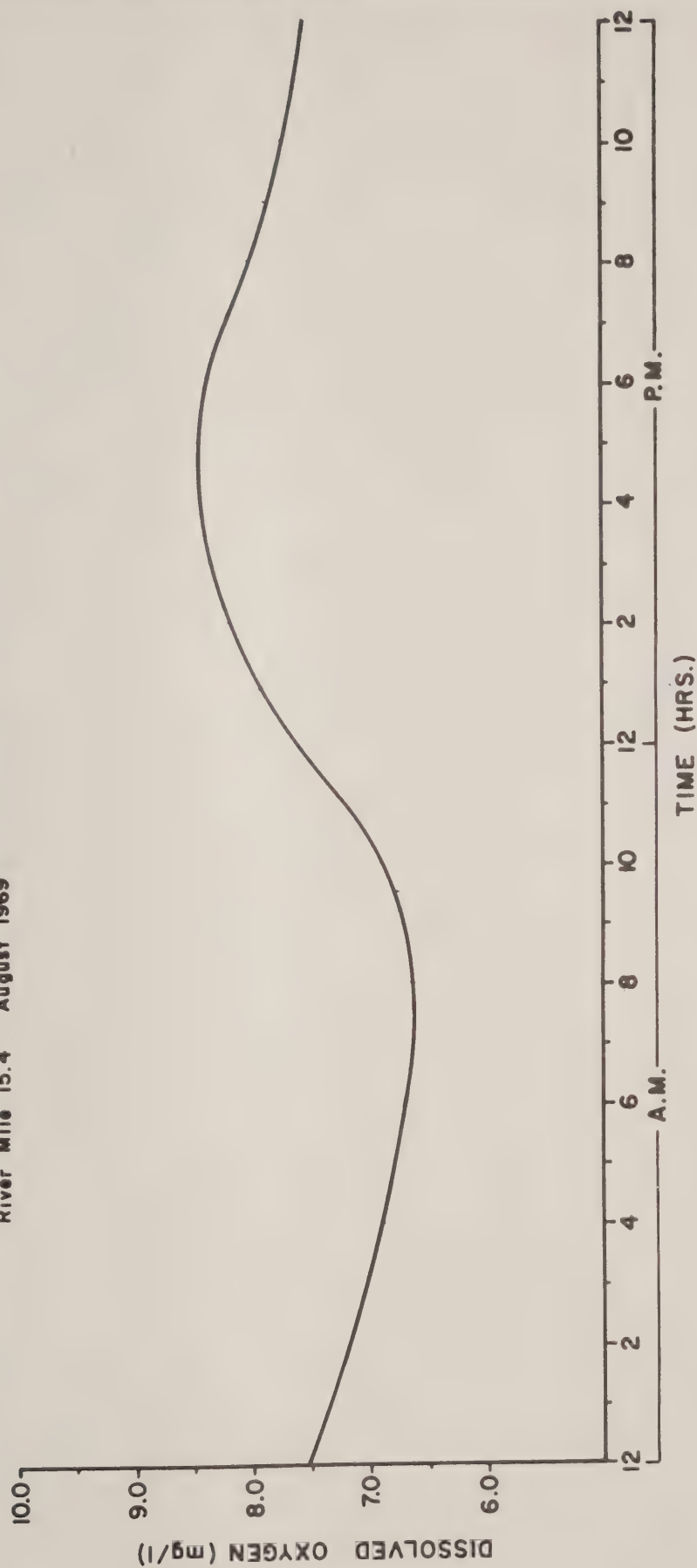


FIGURE E-12

NOTE:

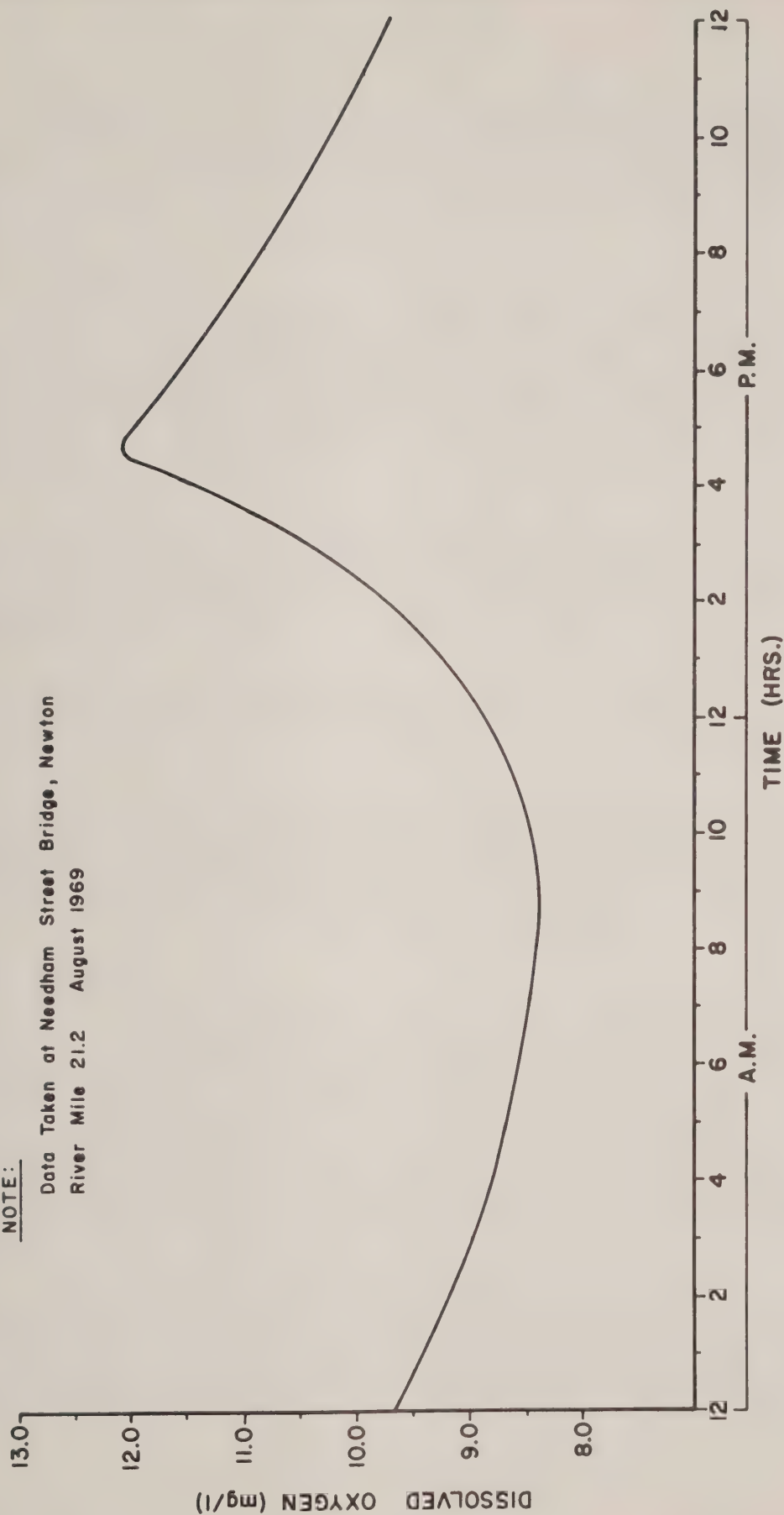
Data Taken at Commonwealth Avenue Bridge, Newton
River Mile 15.4 August 1969



DIURNAL FLUCTUATION OF DISSOLVED OXYGEN

NOTE:

Data Taken at Needham Street Bridge, Newton
River Mile 21.2 August 1969



DIURNAL FLUCTUATION OF DISSOLVED OXYGEN

The majority of dissolved oxygen analyses were performed on samples collected in the morning hours when dissolved oxygen levels are below the average daily concentration. Thus, dissolved oxygen profiles based on these observations would tend to be nearer minimum than average values.

(5) Temperature

For warm water fisheries in Massachusetts such as the Charles River, in order to maintain a Class B or Class C water, allowable temperature increases are "None except where the increase will not exceed the recommended limits on the most sensitive receiving water use and in no case will exceed 83°F (28.3°C) in warm water fisheries, or, in any case, raise the normal temperature of the receiving water more than 4°F."

River temperatures measured during the July and August 1967 survey averaged 23°C in the upper reaches of the Charles and slowly increased to an average of 25°C at the Moody Street Dam. Maximum temperatures ranged from 25°C in the upper reaches to 27°C at the Moody Street Dam.

During July and August 1969 maximum temperatures found in the upper Charles were 25°C, and 27°C in the middle portions of the stream.

During September 1967, the Massachusetts Division of Water Pollution Control measured temperatures as high as 26°C in the Upper Charles River. On occasion, temperatures have been recorded as high as 29°C to 30°C by the Massachusetts Department of Health at several points in the upper and middle portions of the river.

(6) Bacteria

Since coliform bacteria are found in the intestinal tract of animals, including man, and are easily measured, they are used as an indicator of fecal pollution and the possible presence of pathogenic organisms. When coliform bacteria exceed an average value of 1,000 per 100 ml during any monthly sampling period, or 2,400 per 100 ml in more than 20 percent of the samples examined during that period, the water is considered unsafe for bathing and other water contact sports by the Commonwealth of Massachusetts and, therefore, does not meet a B classification.

In 1967 and 1969 at all Charles River sample stations, average coliform concentrations exceeded 1,000 organisms per 100 ml. The highest values were found below sources of domestic waste. During the sampling periods, several waste dischargers did not chlorinate their effluents, although they do now. Urban runoff is

another source of bacterial pollution that affects the Charles River. During periods of rainfall, substantial numbers of bacteria can be added to the stream (see Table E-7).

(7) Color and Turbidity

For Class B and Class C streams, the color and turbidity of a body of water should not impair assigned uses.

In its Health Guidelines for Water Resource and Related Land Use Management, the U.S. Public Health Service has recommended that for water contact sports, the color should not exceed 15 standard units. This recommendation is designed chiefly for the safety of the water users.

The color along the entire length of the Charles River was high. Average values varied from a low of 71 color units below Milford to a high of 166 color units at Medway (Station C-4). Between Station C-6 in Medfield and the Moody Street Dam in Waltham, the average color was relatively constant, within a range of 121 and 142 units. Most of the color imparted to the stream is probably of natural origin. Rivers such as the Charles that drain through extensive swampy areas are noted for their brown, "tea-like" color.

The U.S. Public Health Service also recommends that turbidity not exceed 30 standard units. Turbidity is a measure of the interference of the material to transmit light to the water, and also gives an indication of the amount of suspended materials in the water. Industrial and municipal discharges, as well as urban runoff, can add significant amounts of suspended materials to a stream. The presence of algae also causes turbidity. Average turbidity concentrations measured in the Charles River in 1967 ranged from a high of ten standard units in the Wellesley-Newton area to a low of five standard units at Medway.

Under the State Sanitary Code, enforced by the Massachusetts Department of Public Health, "Bathing and swimming shall not be permitted in water areas when ...a black disk, six inches in diameter, on a white field placed at a depth of at least four feet of water is not readily visible from the surface of the water, or when, under normal usage, such disk is not readily visible from the surface of the water when placed on the bottom where the water depth is less than four feet..."

In September 1970 on a bright, cloudless day, personnel of EPA conducted a survey of the Class B section of the Charles River to determine at what depth an approved disk became invisible. Readings were taken at 11 locations between Bridge Street in Dover and the Watertown Dam. In addition to the disk measurements, true and apparent color and turbidity were analyzed.

The disk was not visible at any location at a depth of four feet. In fact, the disk became invisible at depths that ranged from 1.25 feet to 2 feet.

The color was fairly constant in the 35 mile reach. Apparent color varied from 80 to 100 color units and true color (measured after the removal of turbidity) between 35 to 45 color units. Turbidity was low, varying from five standard units to nine standard units.

(8) Bottom Organisms

Macrobenthic invertebrate surveys serve as an excellent indication of both gross pollution and subtle changes in the aquatic environment.

Unpolluted waterways support many kinds of bottom dwelling insects (clean-water organisms) such as caddisflies, mayflies, stoneflies, and certain beetles. Because of predators and competition for food, these organisms are relatively few in number. Yet, grossly polluted waters, which are low in dissolved oxygen and rich in settled organic sludges, support only a few types of organisms such as sludge-worms and bloodworms. These organisms are usually found in great numbers due to the lack of predators and the unlimited food supply.

Grossly polluted conditions existed on the Charles River below the Milford sewage treatment plant. Here, 4,319 organisms per square foot were found. Although there were 11 different types of organisms, 3,744 were the pollution tolerant sludgeworm. In contrast, at river mile 34.5 in the Needham-Dover area, the river was relatively unpolluted. At this location, 24 kinds of organisms were found. Total numbers of organisms per square foot were 338, of which one was considered a pollution tolerant organism. Figure E-15 indicates the number of species and total numbers of organisms found along the Charles River at each sampling station.

b. Present Waste Load

(1) Point Sources of Pollution

During the fall and winter of 1967 and 1968, sources of wastes discharged to the waters of the Charles River Watershed were inventoried by personnel of EPA and the Massachusetts Division of Water Pollution Control. After a preliminary location survey, each source of waste was sampled over an eight hour period and analyzed for various constituents. Where necessary, a source of waste was sampled on more than one day.

The location of each waste source is shown on Figure E-16, and the quantity of BOD₅ and total phosphate as P contributed by

each source are presented on Table E-5. The total raw BOD₅ load from major sources is approximately 8,300 lbs/day (pounds per day), while after treatment 3,100 lbs/day are discharged to the river, a net removal of 63 percent.

Wastes are contributed by municipalities, industry and institutions, like a hospital and a prison. The BOD₅ from each type is shown on Table E-6. Although industrial sources account for only 19 percent of the total raw load, because of little treatment afforded industrial wastes, they contribute 50 percent of the BOD₅ discharged to the Charles.

(2) Other Sources of Waste

Non-point sources of waste also contribute pollutants to the waters of the Charles River Watershed. In the upper reaches above Needham, much of the population discharges its waste through individual disposal systems. In at least two areas, this method of disposal has become inadequate and overflows of septic tank effluent are reaching the Charles River and tributary streams.

In the middle section of the stream from Needham to the Moody Street Dam, there are few, if any, identified point sources of pollution. The wastes discharged to the sewerage systems of each community in this section are conveyed out of the basin and discharged after treatment to Boston Harbor by the Metropolitan District Commission. Each community has a separate sewerage system, that is, a sewerage system with separate sanitary sewers and storm drains. However, wastes are added to the watercourse as a result of urban rainfall runoff. Accumulations of street litter; dirt and dust; oils; salt; pesticides, herbicides and fertilizers; possible cross-connections of sewage to storm drainage systems; and other sources may add significant quantities of pollutants to streams during periods of rainfall.

Samples from three storm sewer overflow points in Wellesley on a rainy day, November 7, 1968, illustrate pollution from urban runoff. Three samples were collected at each outfall--the first near the beginning of the rainfall, and hourly thereafter. Five-day BOD concentrations and coliform bacteria were measured and, where possible, the discharge of the overflow estimated. The results are shown in Table E-7. In all cases coliform concentrations were above 1,000 organisms/100 ml and at two of the overflow points, above 100,000 organisms/100 ml. The River Street storm drain, which collects storm runoff from the commercial section of Wellesley, contained substantial quantities of BOD₅. The results clearly show that pollutants added from numerous storm drains to waterways from urban runoff are substantial, and can adversely affect legitimate uses of the receiving water.

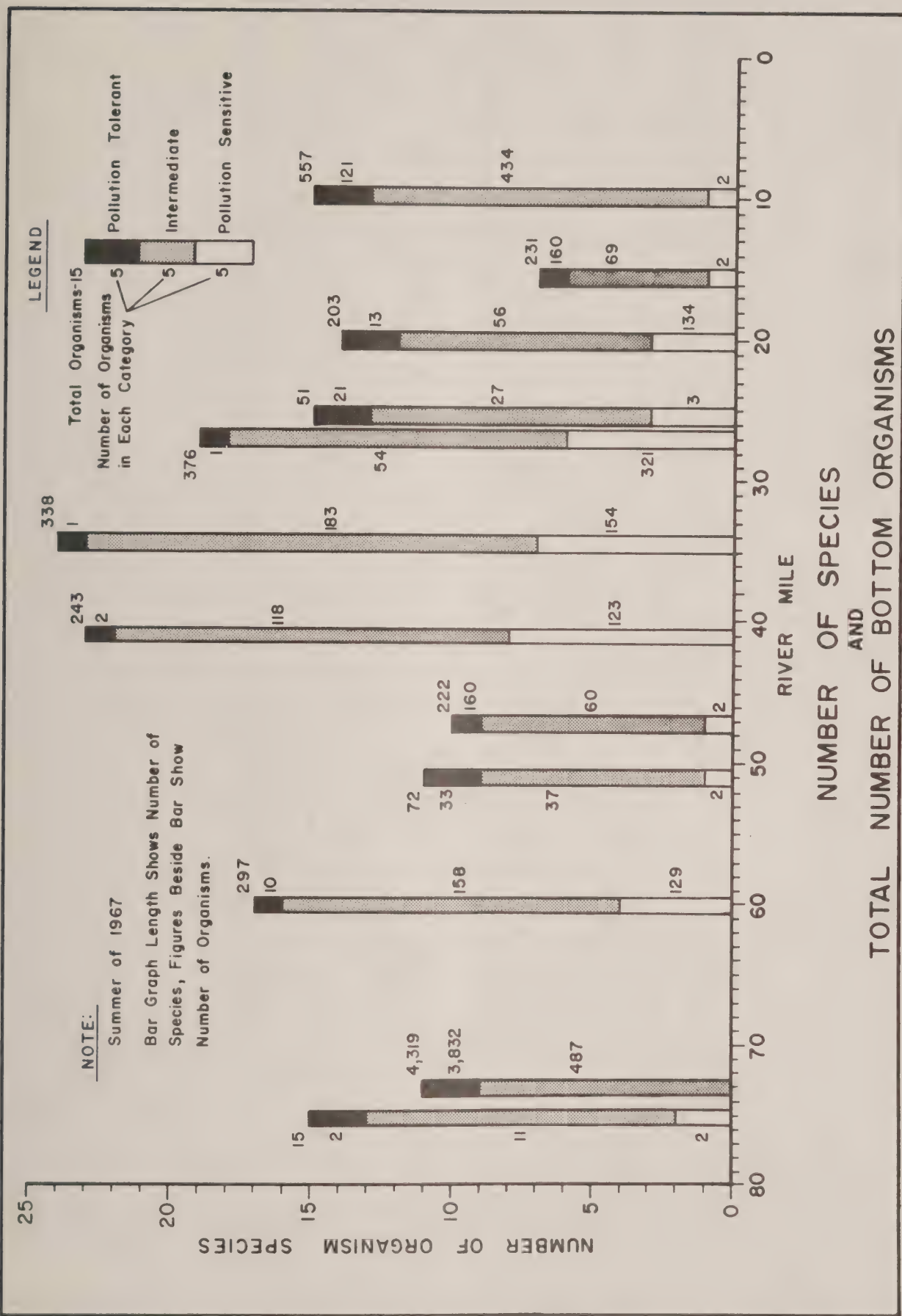


FIGURE E-15

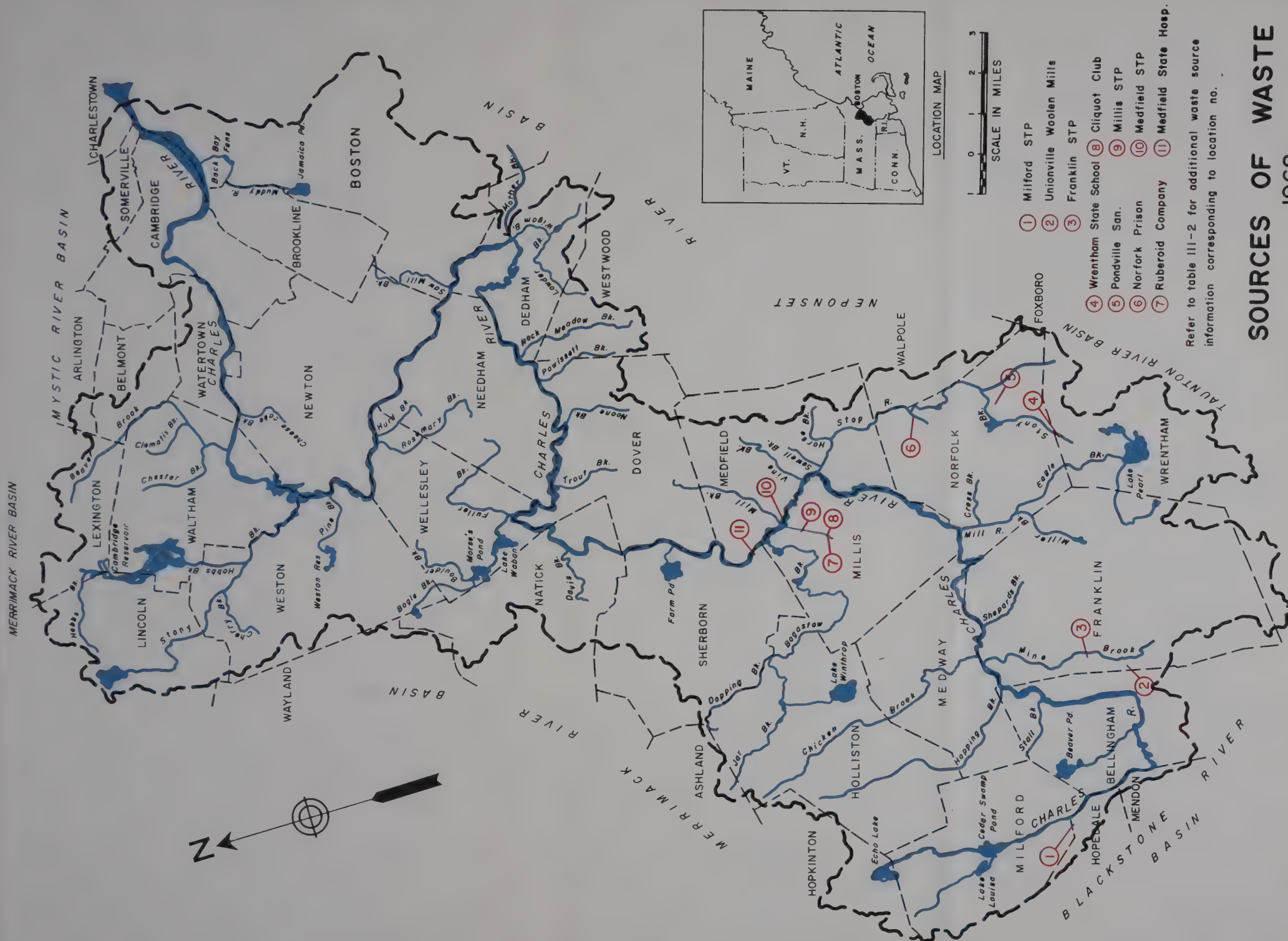


FIGURE E-16

TABLE E-5

CHARLES RIVER WATERSHED STUDY

Major Sources of Organic Waste - 1968

Location Number	Name of Waste Source	Location by River Mile	Type of Waste	Present Treatment	Waste Discharge (mgd)	BOD ₅ Before Treatment (lbs/day)	BOD ₅ After Treatment (lbs/day)	Total Phosphate as P (lbs/day)
1	Milford STP ¹	73.4	Municipal	Secondary	1.5	1,930	360	104
2	Unionville Woolen Mills, Franklin	63.2-4.1 (Mine Brook)	Textile	None	.15	110	110	-
3	Franklin STP	63.2-3.4 (Mine Brook)	Municipal	Secondary	1.2	1,960	660	77
4	Wrentham State School, Wrentham	51.8-6.5-1.1 (Stop River)	Domestic	Secondary	.3	390	200	19
5	Pondville Sanitarium, Norfolk	51.8-6.7 (Stop River)	Domestic	Intermittent Sand Filters	.05	60	10	2
6	Norfolk Prison, Norfolk	51.8-3.4 (Stop River)	Domestic	Intermittent Sand Filters	.4	1,470	170	25
7	Ruberoid, Millis	49.8-1.6	Shingles	Lagoons	.2	15	10	-
8	Cliquot Club, Millis	49.8-1.6	Carbonated Beverages	None	.2	1,440	1,440	66
9	Millis STP	49.8-1.1	Municipal	Secondary	.2	370	40	12
10	Medfield STP	49.2-1.9	Municipal	Intermittent Sand Filters	.1	95	35	9
11	Medfield State Hospital, Medfield	47.5	Domestic	Intermittent Sand Filters	.3	420	75	16
Total					4.6	8,260	3,110	330

1. STP = Sewage Treatment Plant

TABLE E-6

CHARLES RIVER WATERSHED STUDY

Quantity of BOD₅ Discharged to
Charles River Watershed by Type - 1968

Source Type	Raw BOD ₅ Load (lbs/day)	% of Total Raw Load	BOD ₅ Load After Treatment (lbs/day)	% of Treated Load	% Removal By Treatment
Municipal	4,355	53%	1,095	35%	75%
Industrial	1,565	19%	1,560	50%	0.3%
Institutional	2,340	28%	455	15%	81%
Total	8,260	100%	3,110	100%	--

TABLE E-7

CHARLES RIVER WATERSHED STUDY

Results of Stormwater Overflow Analyses

Rainfall - November 7, 1968 - As Measured at Logan International Airport, Boston

<u>Time</u>	<u>Inches</u>
10-11 am	0.00
11-12 am	.04
12-1 pm	.03
1-2 pm	.01
2-3 pm	.07
3-4 pm	.10

Station 1 - 30 inch overflow at River Street, Wellesley

<u>Time</u>	<u>Discharge</u>	<u>Total Coliforms</u>	<u>BOD₅</u>
12:00 noon	-	600,000 org./100 ml	200 mg/l
1:20 pm	-	280,000 org./100 ml	>86 mg/l
2:25 pm	-	500,000 org./100 ml	48 mg/l

Station 2 - 15 inch overflow at Mica Lane, Wellesley

<u>Time</u>	<u>Discharge</u>	<u>Total Coliforms</u>	<u>BOD₅</u>
12:15 pm	16 gpm ¹	4,700 org./100 ml	38 mg/l
1:30 pm	14 gpm	9,400 org./100 ml	12 mg/l
2:30 pm	29 gpm	22,000 org./100 ml	9 mg/l

Station 3 - 15 inch overflow at Boulevard Road, Wellesley

<u>Time</u>	<u>Discharge</u>	<u>Total Coliforms</u>	<u>BOD₅</u>
12:30 pm	none	-	-
1:35 pm	4.4 gpm	400,000 org./100 ml	>6 mg/l
2:40 pm	115 gpm	190,000 org./100 ml	20 mg/l

1. gpm - gallons per minute

Drainage from improperly located solid waste disposal facilities is another source of pollution that affects the Charles River and tributary streams--many communities, mainly for economic reasons, have located sanitary landfills in low marsh areas where direct runoff to nearby water bodies occurs. Drainage from sanitary landfills contains significant bacterial concentrations, and have a high organic load and low dissolved oxygen concentrations. The Massachusetts Division of Water Pollution Control has ordered three Charles River communities to abate pollution caused by sanitary landfills.

During 1970, the Massachusetts Department of Public Health conducted an inventory of all solid waste disposal facilities in the State. Each disposal site was located on Geological Survey maps. Based on the results of the survey, approximately 15 communities have improperly operated solid waste disposal facilities in areas that could cause pollution of waters in the Charles River Watershed.

c. Present Water Use

(1) Water Supply

Nineteen communities take water from within the watershed for water supply. Only Milford, Lincoln and Cambridge have surface water sources, while the others have ground water supplies.

Milford withdraws water from Echo Lake at the headwaters of the Charles River. The safe yield of this source is 1.0 mgd. In Lincoln, Sandy Pond with a safe yield of 1.2 mgd is the source of supply. The City of Cambridge controls the drainage of the Stony Brook Watershed which is located in Weston, Waltham, Lexington and Lincoln. The safe yield of this source is approximately 13.7 mgd.

Several industries use water from the watershed, primarily for cooling purposes. The quantity of cooling water used is not known. Process water use which is not supplied by municipal systems within the study area is in the order of 3 mgd.

(2) Recreation

Practically every long-time resident of the watershed knows of someone who used to swim in the Charles or has swum there himself. People would go to the several public beaches or to some spot where the shore gave good access. It has been almost twenty years since the last public beach was closed (at the South Natick Dam in 1953). High bacterial concentrations and excessive turbidity and color (partly because of algae growths) in the river and its tributaries have prevented swimming and limited other water sports. Now only a few lakes at the headwaters of contributing streams are open for swimming. Pollution fed algae and an unpleasant appearance do not encourage picnicking, park development and intensive use of the river banks.

Historically, canoeing has been extremely popular in the middle and upper river; the demand for this pastime has recently been gaining momentum again. However, after the Norumbega Boat House in Newton burned in 1959, the YMCA's Red Wing Bay Center in Charles River Village (Needham) remained the only canoe rental place above the Boston metropolitan area. Above Millis, except during low flow periods, one can paddle from the West Medway Dam to the South Natick Dam, a distance of almost 21 miles. Present use, nonetheless, is limited.

Sport fishing in the Charles is generally marginal, although the State Division of Fisheries and Game considers that a condition of underharvesting exists along the whole river. The Division has been stocking rainbow and brook trout for some time, and in the spring of 1971 began a brook trout tagging project at Shepherd, Vine and Bogastow Brooks and on the mainstem at Norfolk, Millis, Dover and Natick. Surprisingly, the biggest trout caught in the State during 1970 was found in the Charles: a brown trout weighing 9-3/4 pounds caught by a boy in Needham.

In much of the upper valley, the rural scenery is a pleasant mix of woods, rock outcroppings and meadows. The river meanders through marshes, with only scattered houses. The extensive wetlands of Medfield and Millis are an important staging and breeding area for migrating waterfowl and nursery area for fish.

The upper and middle Charles River areas possess a strong potential for moderate and low intensity recreation use and sport fishing. This potential, at present, is inadequately served, largely due to pollution factors. Unsightly algal conditions, oil scums, debris and turbidity create an unpleasant setting that is not attractive to people bent on recreation. Low oxygen contents and other adverse factors in the water inhibit the growth and reproduction of a balanced aquatic biota and sport fishery. Improper control of sewage flows poses a health threat to those who might come in contact with the water. A major pollution abatement program aimed at the entire range of water quality problems is essential to improved water use and fulfillment of the river's recreation potential.

4. FUTURE POPULATION AND ECONOMY

The U. S. Army Corps of Engineers, as part of the Charles River Study, has developed land use, population, and economic data bearing on present and future uses of water and related land resources. The population projections, which extend to the year 2020 for the cities and towns within the watershed, were coordinated with the Metropolitan Area Planning Council, the Department of Agriculture and the Environmental Protection Agency, and distributed to all coordinating committee members. They are consistent with projections made on a county basis by the Office of Business Economics, U. S. Department of Commerce. Table E-8 shows the projections, divided into Upper and Lower Charles Communities, of both the total municipality population and the portion of the population within the watershed.

As shown in the Table, substantial growth in the Upper watershed is expected. The projected 2020 Upper watershed population of 507,000 is about 3.7 times greater than the 1960 population. The Lower Charles communities are expected to continue their slight decline until 1980 and then increase to the year 2020. Between 1980 and 2020 the Lower Charles communities are expected to grow by a factor of 1.15.

The rapid growth in the Upper watershed is due in part to the expected continued migration from urban Boston to the suburbs. Future growth and industrial development is also expected as a result of the recently constructed Interstate Route 495 expressway which runs generally north/south through the communities of Hopkinton, Milford, Bellingham, Franklin, and Wrentham.

Figures E-17 through E-19 illustrate the future expected distribution of population for the years 1980, 2000, and 2020. In 1960 most of the Upper Charles communities had population densities of less than 500 persons per square mile. By 2020 the majority will have densities greater than 1,000 persons per square mile.

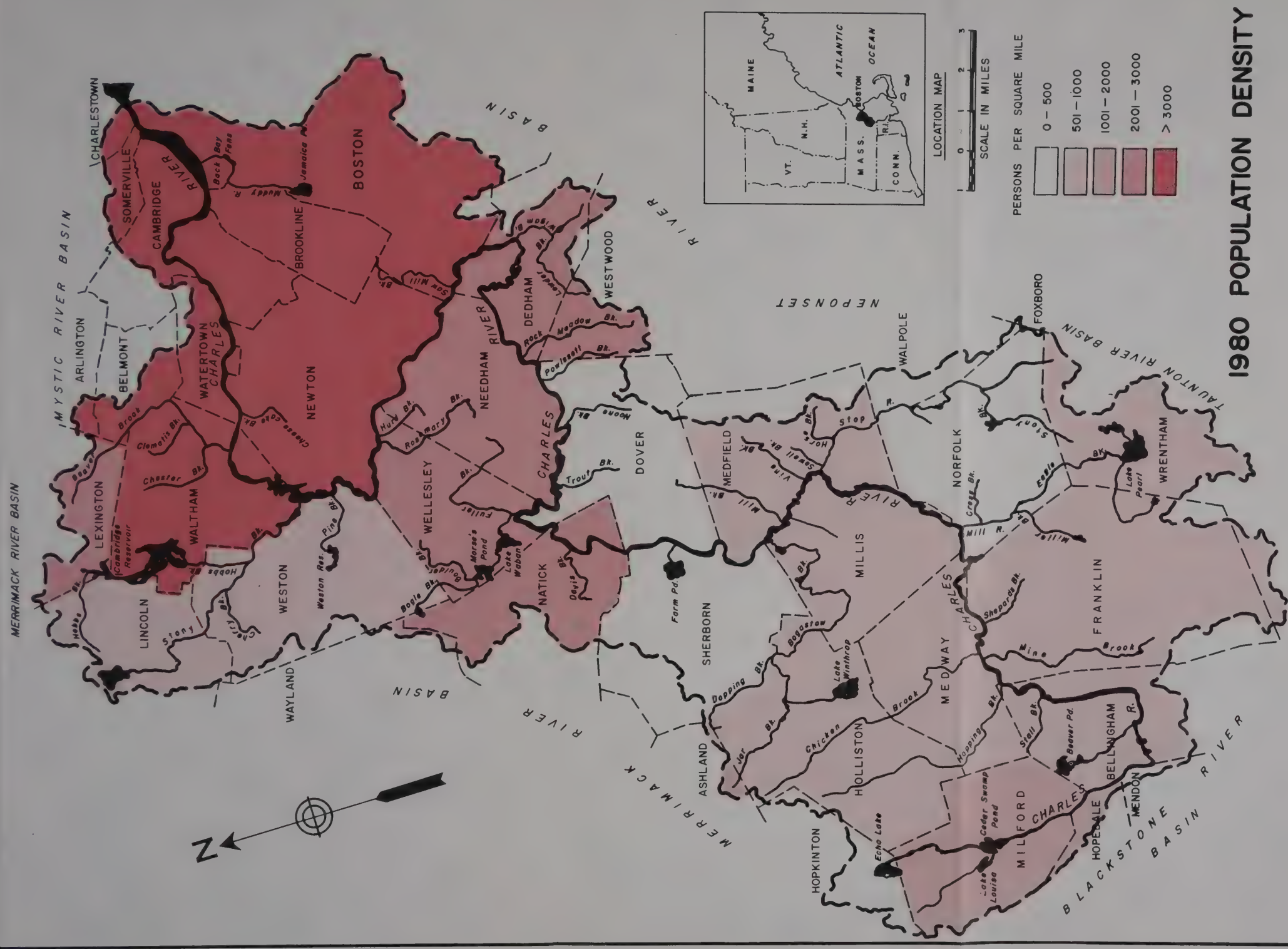


FIGURE E-17

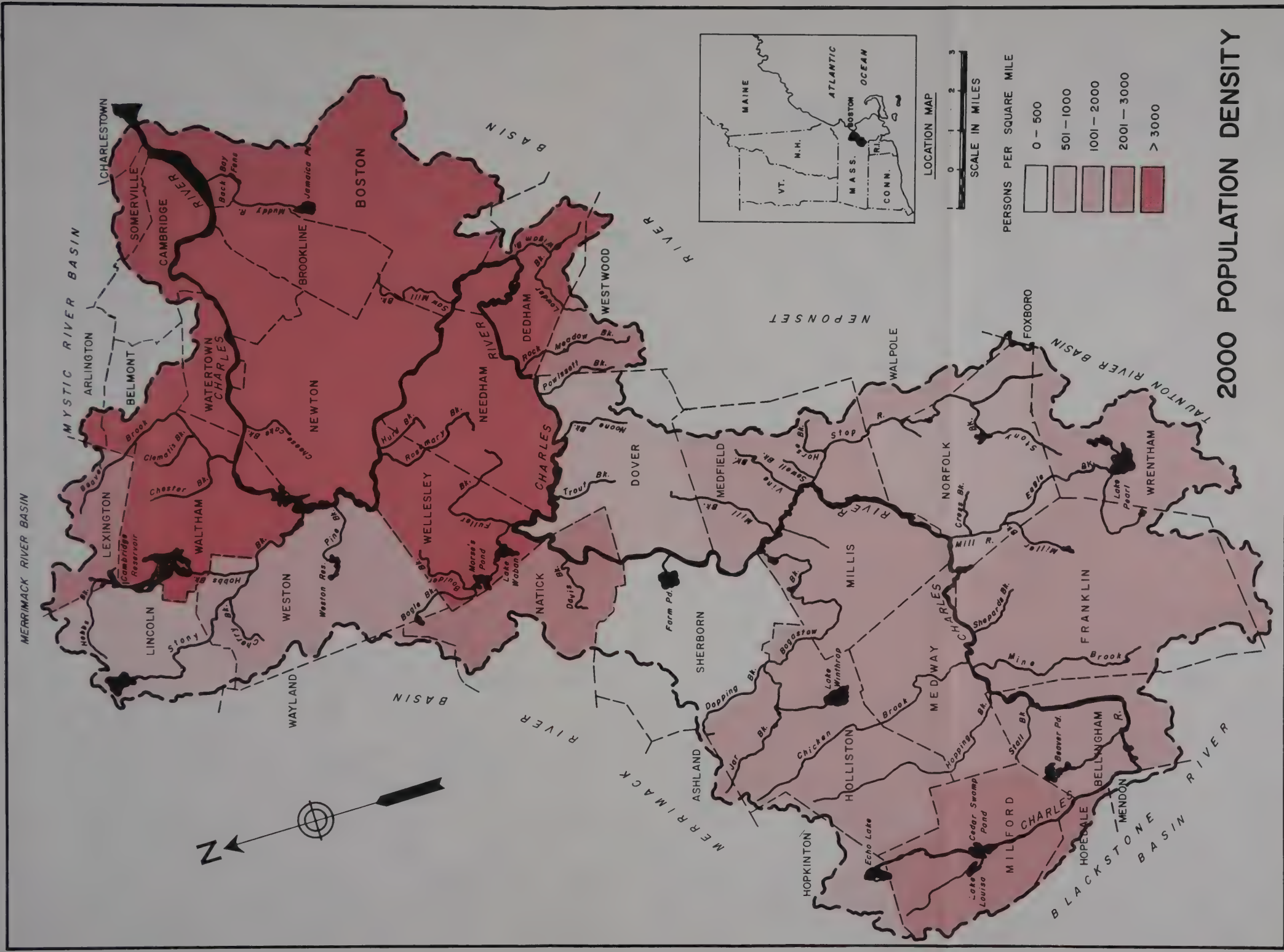


FIGURE E-18

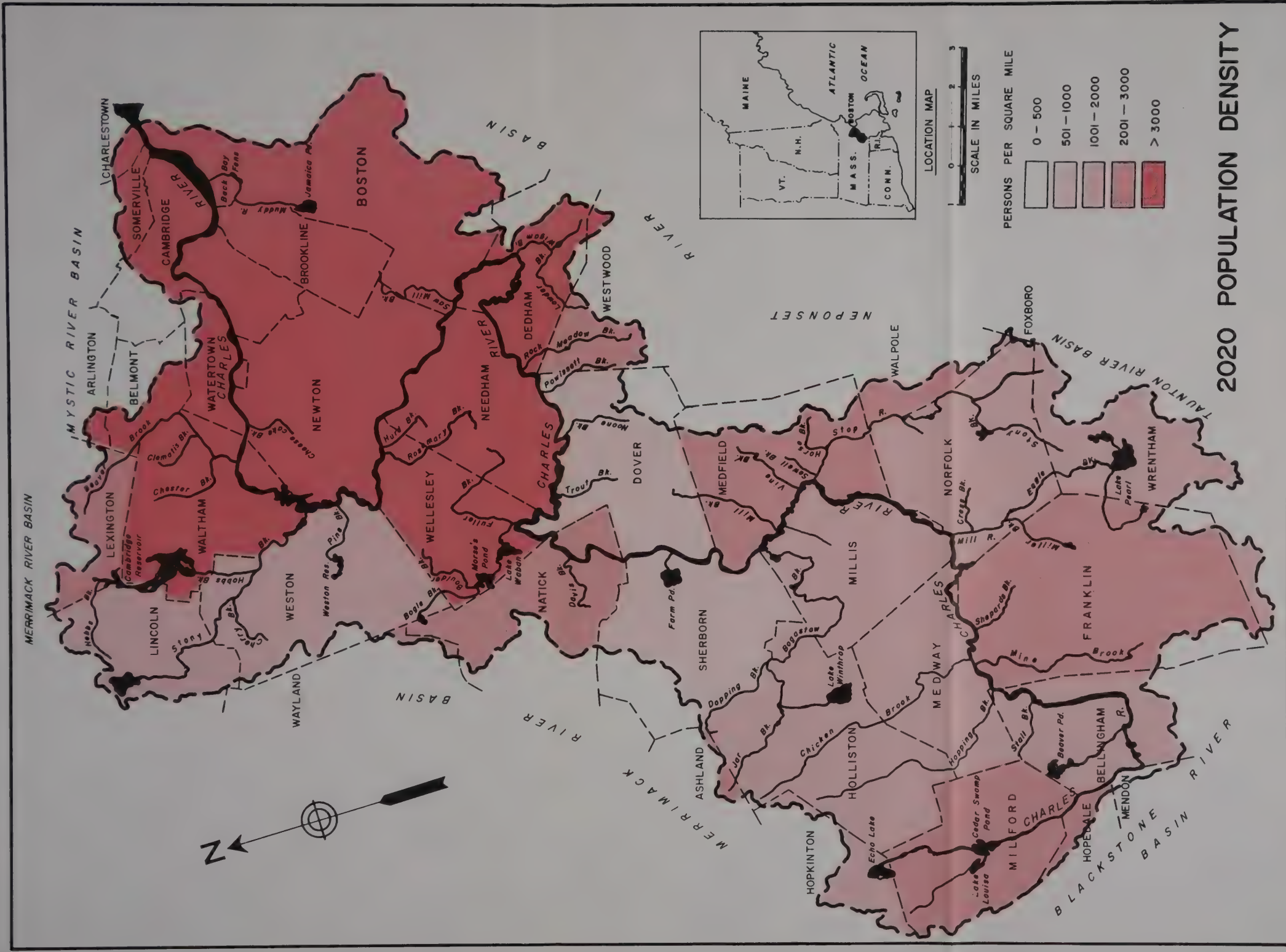


FIGURE E-19

TABLE E-8

CHARLES RIVER WATERSHED STUDY

Projected Population

	<u>Total Municipality</u>			<u>Watershed Portion</u>				
	U. S. Census 1960	1980	2000	2020	Est'd 1960	1980	2000	2020
Upper Charles	138,600	241,000	381,000	507,000	65,775	126,120	201,030	274,540
Lower Charles	1,360,155	1,323,000	1,447,000	1,579,000	733,610	753,650	822,600	898,800
Total	1,498,755	1,564,000	1,828,000	2,086,000	799,385	879,770	1,023,630	1,173,340

Lower Charles Municipalities

Arlington	Needham
Belmont	Newton
Boston	Somerville
Brookline	Waltham
Cambridge	Watertown
Dedham	Wayland
Dover	Wellesley
Lexington	Weston
Lincoln	Westwood

Upper Charles Municipalities

Ashland	Mendon
Bellingham	Milford
Foxboro	Millis
Franklin	Natick
Holliston	Norfolk
Hopedale	Sherborn
Hopkinton	Walpole
Medfield	Wrentham
Medway	

5. FUTURE WASTE LOADS AND WATER QUALITY

a. Waste Loads

(1) Point Sources

Of the 35 cities and towns that lie wholly or partially within the watershed, 17 dispose of municipal wastes through the MDC system, four discharge municipal wastes to the waters of the Charles River Watershed, two discharge municipal wastes to other basins, and 12 presently have no municipal sewerage systems. In the future, as municipalities grow and require sewerage systems, we estimate that ten communities will discharge municipal wastes to the waters of the watershed. The future population of these communities is shown on Table E-9. Other communities within the watershed should continue to discharge wastes outside of the watershed or will likely do so in the future.

Also shown on Table E-9 are estimates of the population within each community that will be served by municipal sewerage systems. These estimates are based on the percentage of people served by municipal sewerage systems at the present time in over 30 cities and town in the Boston area as compared with the population density of each community. The percentage served for each population density range was established (Table E-10) as a basis for the estimates of future numbers of people to be served by waste treatment plants in the Charles River communities.

In 1965, approximately 18,500 persons were served by sewerage systems in the towns of Milford, Franklin, Millis and Medfield, which was only 42 percent of the total population of the four communities. The average per capita waste load from the four towns was 0.24 pounds of BOD₅ per day. In these communities, the per capita raw waste load is relatively high because large flows and loads are contributed by their commercial centers. As more residential areas become sewered, the per capita waste load will decrease. However, decreases in the per capita waste flow as a result of added residential areas will be offset by industrial inputs to the system. Therefore, for the projection years, it was assumed that each person will contribute 0.25 pounds of BOD₅ per day which includes an allowance for industrial additions to the sewerage systems.

Table E-11 shows the raw waste loadings anticipated for the ten communities expected to discharge to the Charles River, and also indicates possible locations of treatment plants by river mile for both an individual community and an alternate regional waste treatment plant scheme. Locations were changed on the basis of general knowledge and cursory map studies. Final locations should be selected only after completion of more detailed investigations involving subsurface conditions, local population and sewer service area trends,

TABLE E-9

CHARLES RIVER WATERSHED STUDY

Projected Population and Population Served by Sewerage Systems

Charles River Watershed Communities

Community ¹	1965		1980		2000		2020	
	Pop.	Pop. Served	Pop.	Pop. Served	Pop.	Pop. Served	Pop.	Pop. Served
Bellingham (50%) ²	5,300	0	9,000	2,700	14,000	7,000	18,500	13,000
Franklin	14,700	4,500	22,000	8,800	41,000	20,500	60,000	48,000
Holliston	8,900	0	14,000	4,200	21,000	8,400	28,000	14,000
Medfield	7,500	1,000	12,000	3,600	22,000	11,000	32,000	25,600
Medway	6,900	200	10,000	3,000	15,000	6,000	20,000	12,000
Milford	17,000	12,000	24,000	17,600	33,000	26,000	42,000	42,000
Millis	5,300	1,000	9,000	2,700	16,000	8,000	22,000	13,200
Norfolk	4,000	0	6,000	0	11,000	2,200	17,000	6,800
Sherborn	2,300	0	4,000	0	7,000	800	10,000	2,200
Wrentham	7,500	0	13,000	2,600	25,000	10,000	33,000	16,500
Total	79,400	18,700	123,000	45,200	205,000	99,900	282,500	193,300

1. Other communities within the watershed are expected to continue to discharge wastes outside of the watershed, or are likely to do so in the future.

2. Only 50% of population of Bellingham considered. Assumed 50% of community will discharge waste outside of Charles River Watershed.

TABLE E-10

CHARLES RIVER WATERSHED STUDY

Percent of Community Sewered versus Population Density

<u>Population Density (Persons/Square Mile)</u>	<u>Percent Served</u>
450 or less	0
451-540	10
541-720	20
721-1000	30
1001-1300	40
1301-1600	50
1601-1900	60
1901-2150	70
2151-2400	80
2401-2700	90
2701 or greater	100

NOTE: Percent served per population density range was based on comparing the present population served in over thirty Boston area communities with the population density of the communities.

TABLE E-11

CHARLES RIVER WATERSHED STUDY

Projected BOD₅ Waste Loadings of Charles River Watershed Communities

Community	River Mile of Waste Discharge ¹	1980 Waste Load ² (lbs/day)	2000 Waste Load (lbs/day)	2020 Waste Load (lbs/day)
<u>Individual Waste Treatment Plants</u>				
Milford	73.4	4,400	6,500	10,500
Bellingham	69.1	680	1,750	3,250
Franklin	63.2-3.4	2,200	5,120	12,000
Medway ³	58.7	750	1,500	3,000
Wrentham ³	57.6-3.7	1,040	2,890	4,510
Norfolk ⁴	51.8-3.4	1,530	2,080	3,230
Millis ⁵	49.8-1.1	2,130	3,450	4,750
Medfield ⁶	49.2-1.9	1,320	3,170	6,820
Holliston	48.4-6.0	1,050	2,100	3,500
Sherborn	47.0	0	200	550
Total		15,100	28,760	52,110
<u>Regional Waste Treatment Plants</u>				
Milford	73.4	4,400	6,500	10,500
Bellingham, Franklin, Medway, Wrentham ³	57.5	4,700	11,260	22,760
Norfolk ⁴ , Millis ⁵ , Medfield ⁶ , Holliston	50.3	6,000	10,800	18,300
Sherborn	47.0	0	200	550
Total		15,100	28,760	52,110

TABLE E-11 (Continued)

1. Hyphenated figures indicate discharge is on tributary. The first number locates the tributary's confluence with the Charles River, and the second number is the distance from the confluence to the discharge point.
2. Loads are based on 0.25 lbs. of BOD₅ per capita per day.
3. Includes waste from Wrentham State School - 390 lbs/day.
4. Includes waste from Pondville Sanitarium and Norfolk Prison - 1,530 lbs/day.
5. Includes waste from Cliquot Club and Ruberoid - 1430 lbs/day.
6. Includes waste from Medfield State Hospital - 420 lbs/day.

and land use relationships and needs. The location of the individual and regional plants are shown geographically on Figures E-20 and E-21, respectively.

In a study conducted for the Metropolitan Area Planning Council by Camp, Dresser and McKee, Consulting Engineers, the water consumption and sewage flow of 152 Boston area communities was projected to the years 1975 and 1990. The future per capita sewage flows were assumed equal to 85 percent of the estimated per capita water consumption plus estimates of infiltration into the system. Sewage flows for the present study were based upon interpolation and extrapolation of the Camp, Dresser and McKee estimates of per capita waste flow, modified in some cases and then combined with the estimates of population served for each city and town. Table E-12 is a summation of the projected sewage flows of those Charles River Watershed communities considered likely to discharge wastes to the Watershed for both the individual and regional waste treatment plant schemes.

(2) Non-Point Sources

As the Upper Charles River communities continue to grow, the pollutional load contributed to the stream as a result of urban runoff and drainage from solid waste disposal areas may increase correspondingly unless measures are taken to reduce the pollution. By 2020 population densities of most of the Upper Charles River communities will be greater than 2,000 persons per square mile.

b. Water Quality

(1) Standards Implementation

As mentioned previously, in 1967 the Commonwealth of Massachusetts, after public hearings, established water quality standards which include a pollution abatement schedule for the Charles River. On this basis, all sources of pollution must have approved treatment facilities in operation by 1973 or sooner.

(2) Estimated Quality after Minimum Treatment

The minimum treatment which now must be provided under the Massachusetts water quality standards is secondary treatment. This normally will remove about 85 percent of the suspended solids and BOD₅. In addition, it is anticipated that the State will require some form of nutrient removal for all facilities on the Charles in an effort to control the algal growth problems which are particularly bothersome during critical low flow periods.

As a base level from which alternate measures can be tested, it has been assumed that treatment will be provided which removes

TABLE E-12

CHARLES RIVER WATERSHED STUDY

Projected Waste Flows of Charles River Watershed Communities

Community	River Mile of Waste Discharge ¹	1980 Waste Flow mgd ²	cfs ³	2000 Waste Flow mgd	cfs	2020 Waste Flow mgd	cfs
<u>Individual Waste Treatment Plants</u>							
Milford	73.4	2.0	3.1	3.6	5.6	6.7	10.4
Bellingham	69.1	.3	.4	.9	1.4	1.9	3.0
Franklin	63.2-3.4	2.0	3.1	4.5	7.0	9.5	14.7
Medway	58.7	.3	.5	.8	1.2	1.7	2.6
Wrentham ⁴	57.6-3.7	.7	1.1	1.9	2.9	3.5	5.4
Norfolk ⁵	51.8-3.4	.4	.6	.7	1.1	1.6	2.5
Millis ⁶	49.8-1.1	.8	1.2	1.6	2.5	2.7	4.2
Medfield ⁷	49.2-1.9	.6	.9	1.8	2.8	4.3	6.7
Holliston	48.4-6.0	.5	.8	1.1	1.7	2.0	3.1
Sherborn	47.0	.0	.0	.1	.2	.4	.6
Total		7.6	11.7	17.0	26.4	34.3	53.2
<u>Regional Waste Treatment Plants</u>							
Milford	73.4	2.0	3.1	3.6	5.6	6.7	10.4
Bellingham, Franklin Medway, Wrentham ⁴	57.5	3.3	5.1	8.1	12.5	16.6	25.7
Norfolk ⁵ , Millis ⁶ , Medfield ⁷ Holliston	50.3	2.3	3.5	5.2	8.1	10.6	16.5
Sherborn	47.0	.0	.0	.1	.2	.4	.6
Total		7.6	11.7	17.0	26.4	34.3	53.2

TABLE E-12 (Continued)

1. Hyphenated figures indicate discharge is on a tributary. The first number locates the tributary's confluence with the Charles River, and the second number is the distance from the confluence to the discharge point.
2. Million gallons per day.
3. Cubic feet per second.
4. Includes waste flow from Wrentham State School - 0.3 mgd.
5. Includes waste flow from Pondville Sanitarium and Norfolk Prison - 0.4 mgd.
6. Includes waste flow from Cliquot Club and Ruberoid - 0.4 mgd.
7. Includes waste flow from Medfield State Hospital - 0.2 mgd.

at least 90 percent of the phosphate for all point waste sources. This will normally be accomplished by secondary treatment followed by an advanced waste treatment process of coagulation and sedimentation which also removes at least 90 percent of the BOD₅. The base river flow used to evaluate the effect of treatment is the average seven day flow with a ten year recurrence interval. At the Charles River Village gage, this is 12 cfs. The projected waste flows from municipalities discharging to the Charles River Watershed in the year 1980, 2000 and 2020 are 11.7 cfs, 26.4 cfs and 53.2 cfs, respectively.

Assuming each person contributed .0099 lbs/day of phosphate and that the minimum required treatment will remove 90 percent of the phosphate, the phosphate as P contributed to the Charles River from municipal sewage treatment plants is estimated to be 45 lbs/day in 1980, 100 lbs/day in 2000 and 190 lbs/day in 2020. These values are substantially less than the measured 1968 phosphate load of 330 lbs/day discharged to the Charles River by point sources.

Estimated BOD₅ waste loads that would be discharged to the Charles River and tributaries during the 1980, 2000 and 2020 years following the minimum treatment are shown on Table E-13.

With these waste loads and extreme low river flow conditions, projected dissolved oxygen profiles for individual treatment plants and the regional treatment plant scheme have been estimated and are shown on Figure E-22. In these analyses, a background level of 2 mg/l of BOD₅ was assumed to account for the urban nature of the stream. It can be seen that significant reaches of the mainstem Charles River will not meet the Class C or Class B dissolved oxygen criteria in 1980 even with 90 percent BOD₅ removal. The four tributary streams that would accept treated waste under the individual treatment plant scheme will also be severely degraded below the sewage treatment plant outfalls.

Generally, with treatment plant regionalization, fewer miles of river would not meet water quality standards and the tributary streams would not be affected by pollution from point sources. However, by concentrating the waste load at fewer locations within the degraded reaches, the dissolved oxygen concentrations would be much lower than under the individual treatment plant scheme.

During low flow periods, levels of treatment that remove only 90 percent of the BOD₅ will not prevent severe degradation of significant reaches of the Charles River by 1980. Additional measures will, therefore, be required to achieve the water quality standards.

TABLE E-13

CHARLES RIVER WATERSHED STUDY

Projected BOD₅ Waste Loadings of Charles River Watershed Communities
after Minimum Treatment

Community	River Mile of Waste Discharge	1980 Waste Load (lbs/day)	2000 Waste Load (lbs/day)	2020 Waste Load (lbs/day)
<u>Individual Waste Treatment Plants</u>				
Milford	73.4	440	650	1,050
Bellingham	69.1	68	175	325
Franklin	63.2-3.4	220	512	1,200
Medway	58.7	75	150	300
Wrentham	57.6-3.7	104	289	451
Norfolk	51.8-3.4	153	208	323
Millis	49.8-1.1	213	345	475
Medfield	49.2-1.9	132	317	682
Holliston	48.4-6.0	105	210	350
Sherborn	47.0	0	20	55
Total		1,510	2,876	5,211
<u>Regional Waste Treatment Plants</u>				
Milford	73.4	440	650	1,050
Bellingham, Franklin Medway, Wrentham	57.5	470	1,126	2,276
Norfolk, Millis, Medfield Holliston	50.3	600	1,080	1,830
Sherborn	47.0	0	20	55
Total		1,510	2,876	5,211

6. ALTERNATES FOR MEETING WATER QUALITY GOALS

a. General

As described in the previous chapter, during extreme low flow periods when river temperatures are high, levels of treatment that remove only 90 percent of the BOD₅ will not bring about desired water quality goals in significant reaches of the Charles River and tributary streams.

Additional measures, however, that may be undertaken to meet desired water quality goals include low flow augmentation, advanced waste treatment, combinations of the two, disposal of wastes out of the basin, subsurface disposal and in-stream aeration.

The natural flow of the Charles will be augmented and correspondingly diluted as the volume of highly treated effluent soon increases through time (with population expansion). Particularly as a balance between natural flows and artificial increment is approached and then altered during low flow periods in favor of treated wastewater effluent, the river will benefit from taking in this clean water of higher quality than its own naturally colored and turbid flow. Fish will prosper with the higher dissolved oxygen levels, canoes may be able to travel further, and people will find improved, algae-free, less brown and turbid swimming opportunities.

b. Low Flow Augmentation

Quantities of flow to maintain a dissolved oxygen level of 5.5 mg/l in the Charles River and tributary streams have been computed under the 1980, 2000 and 2020 waste loading conditions corresponding to 90 percent removal of BOD₅ (Table E-13). A dissolved oxygen level of 5.5 mg/l in the stream approximates the Class B and meets the Class C requirements and is suitable for the maintenance of a well balanced fishery.

Flows were determined for stream temperatures of 20°, 25° and 30°C, temperatures that are found between May and October. Augmentation flows were also determined for both the individual waste treatment plant scheme and the regional waste treatment plant scheme (shown schematically in Figures E-20 and E-21) to see what influence plant size and location may have on flow requirements). Quantities of flow needed in the Charles River to maintain an average dissolved oxygen concentration of 5.5 mg/l with minimum levels of treatment are presented on Table E-14. Flow augmentation would be introduced at several locations above major sources of waste. Augmentation water was assumed to contain dissolved oxygen levels equivalent to 88 percent saturation. The distribution of flows for the 1995 and 2020 years at the maximum river temperature of 30°C are shown on Table E-15.

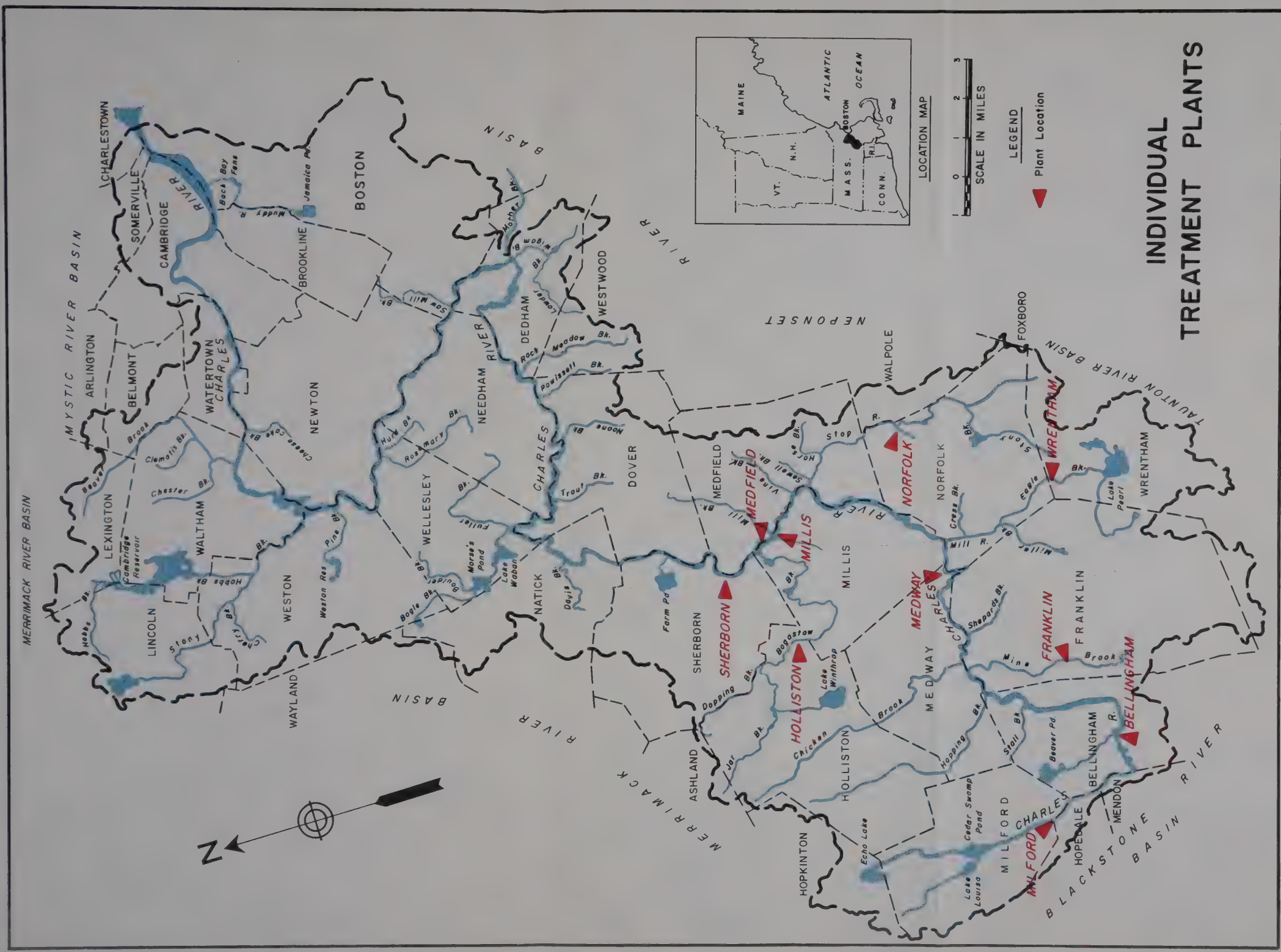


FIGURE E-20

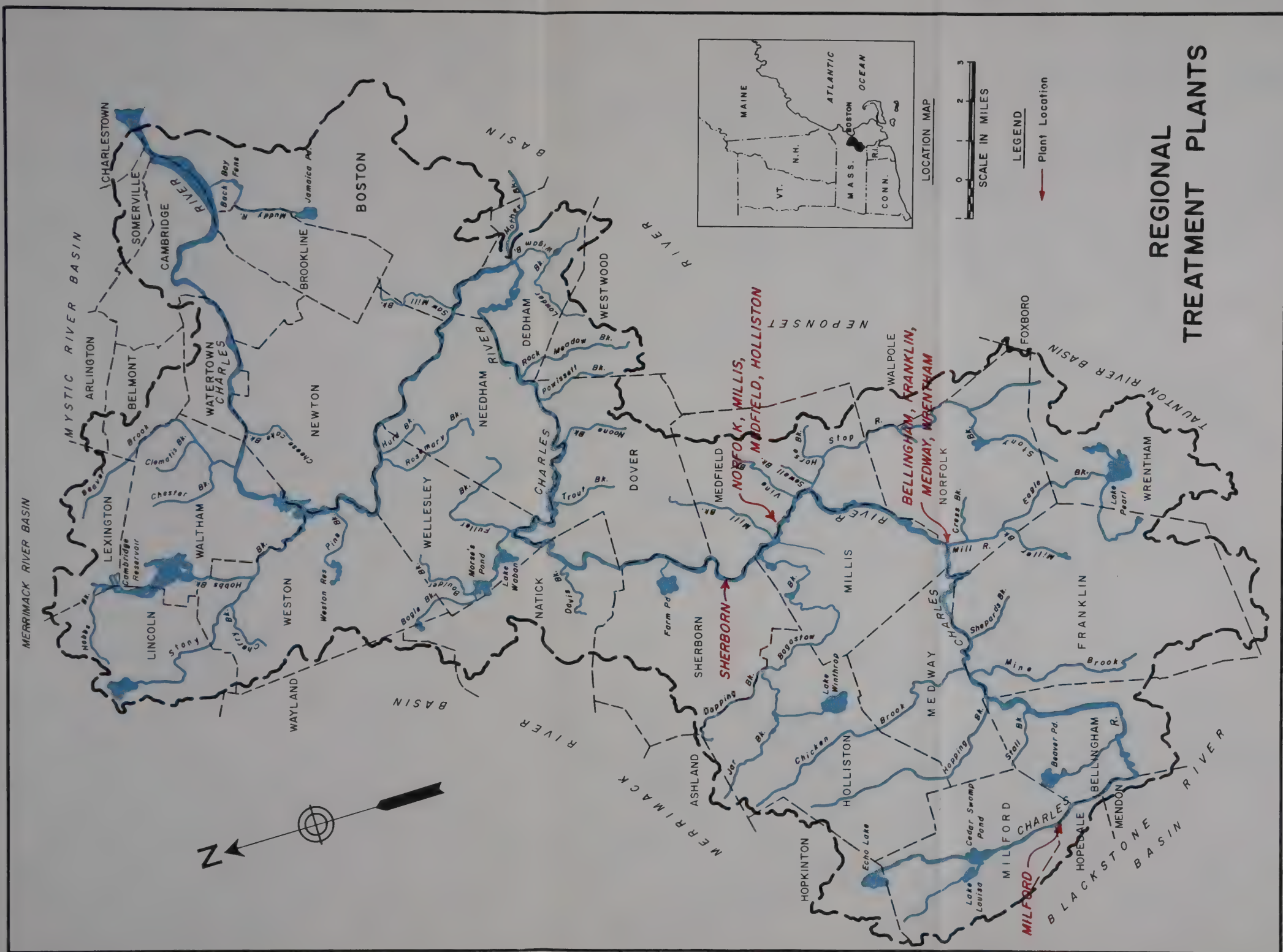
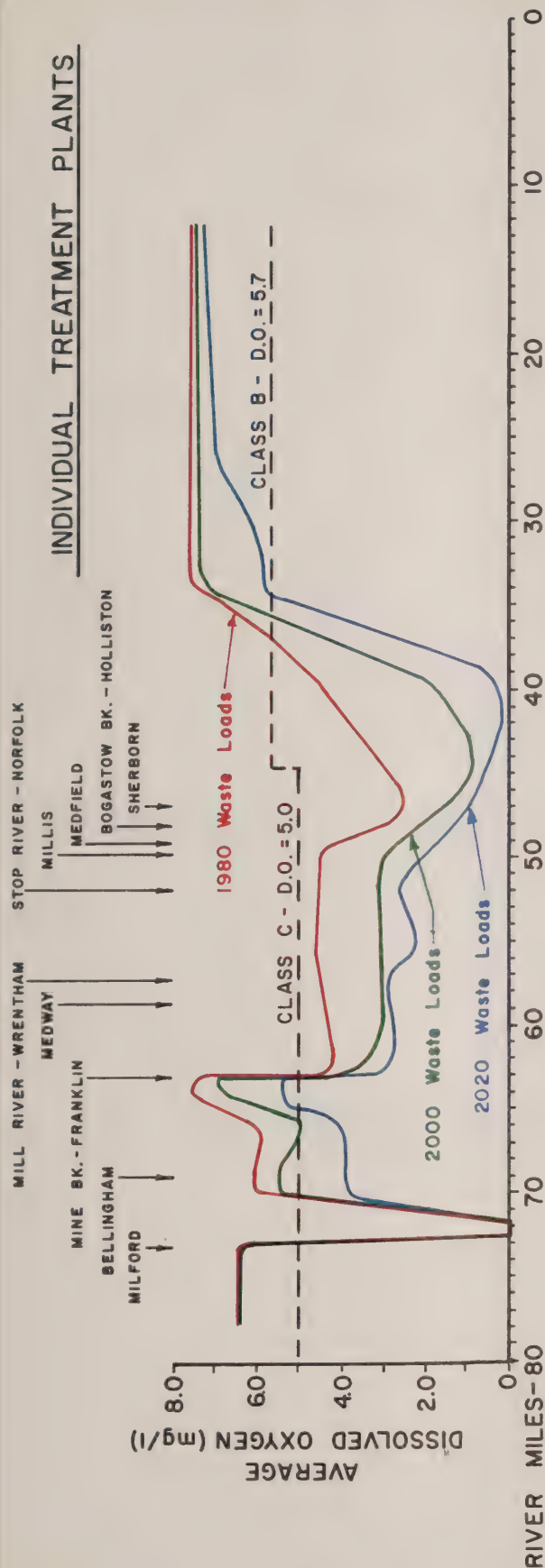
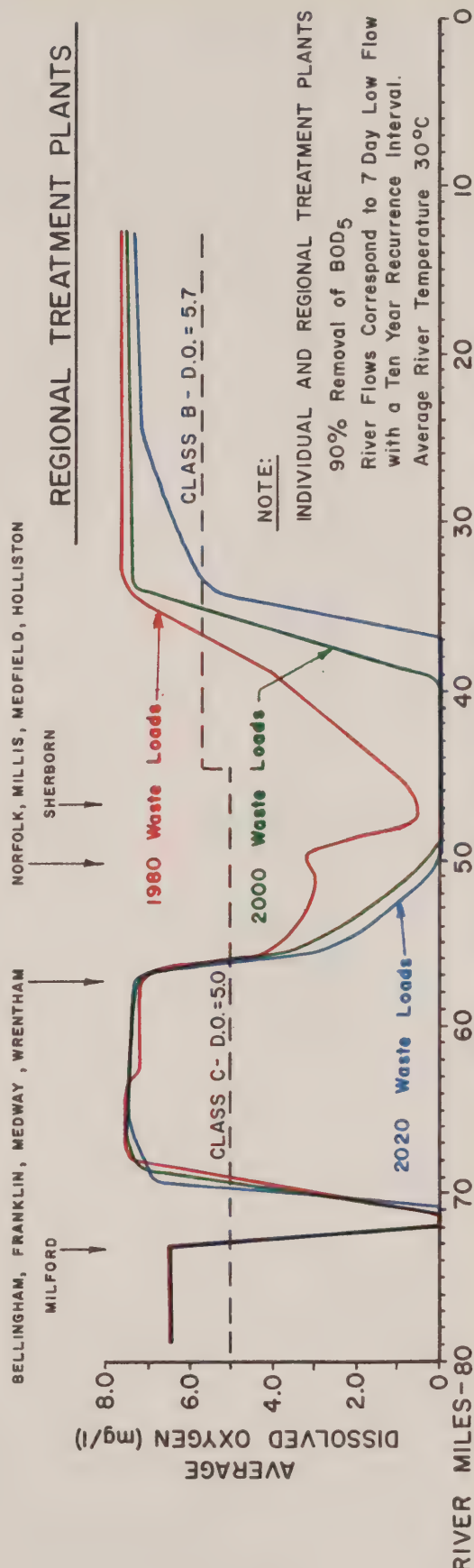


FIGURE E-21

INDIVIDUAL TREATMENT PLANTS



REGIONAL TREATMENT PLANTS



NOTE:

INDIVIDUAL AND REGIONAL TREATMENT PLANTS

90% Removal of BOD₅

River Flows Correspond to 7 Day Low Flow with a Ten Year Recurrence Interval.

Average River Temperature 30°C

PROJECTED DISSOLVED OXYGEN PROFILES

FIGURE E-22

TABLE E-14

CHARLES RIVER WATERSHED STUDY

Flow Augmentation¹ at Minimum Waste
Treatment Levels

<u>1995 Flow Requirement</u>			
<u>Month and River Temperature</u>		<u>Individual Treatment Plants</u>	<u>Regional Treatment Plants</u>
May	20°C	45 cfs	50 cfs
June	25°C	80 cfs	90 cfs
July	30°C	165 cfs	180 cfs
August	30°C	165 cfs	180 cfs
September	25°C	80 cfs	90 cfs
October	20°C	45 cfs	50 cfs

<u>2020 Flow Requirement</u>			
<u>Month and River Temperature</u>		<u>Individual Treatment Plants</u>	<u>Regional Treatment Plants</u>
May	20°C	110 cfs	110 cfs
June	25°C	195 cfs	200 cfs
July	30°C	390 cfs	400 cfs
August	30°C	390 cfs	400 cfs
September	25°C	195 cfs	200 cfs
October	20°C	110 cfs	110 cfs

1. Flow amounts are those needed in addition to the base low flow and waste discharge flows.

TABLE E-15

CHARLES RIVER WATERSHED STUDY

Distribution of Flow Augmentation
River Temperature of 30°C

<u>Individual Treatment Plants</u>	<u>1995</u>	<u>2020</u>
Portion needed above Milford Waste (R.M. 73.4)	60	105
Portion needed above Franklin Waste (R.M. 63.2 - 3.4 Mine Brook)	20	35
Portion needed above Wrentham Waste (R.M. 57.6 - 3.7 Mill River)	13	25
Portion needed above Norfolk Waste (R.M. 51.8 - 3.4 Stop River)	8	10
Portion needed above Holliston Waste (R.M. 48.4 - 6.0 Bogastow Brook)	4	5
Portion needed above R.M. 63.2	<u>60</u>	<u>210</u>
Total Flow Augmentation	165	390
<u>Regional Treatment Plants</u>	<u>1995</u>	<u>2020</u>
Portion needed above Milford Waste (R.M. 73.4)	55	90
Portion needed above Regional Plant at R.M. 57.5 (Bellingham, Franklin, Medway, Wrentham)	125	310
Total Flow Augmentation	<u>180</u>	<u>400</u>

c. Advanced Waste Treatment

(1) General

Processes are available to remove greater amounts of pollutants than is possible with secondary treatment plus coagulation and sedimentation. For example, the addition of rapid sand filtration would remove approximately 93 percent of BOD₅, and a final granular carbon absorption process could be expected to further increase the removal rate to 98 percent. Advanced treatment processes also remove further quantities of suspended solids and phosphates.

The technology of advanced waste treatment is changing rapidly. Thus, while the costs and processes used herein are considered valid for comparing alternate treatment plant configurations for general planning purposes, the actual cost of future construction may vary markedly due to improved processes and operating procedures. Analyses, based on stream flow and quality conditions and waste loads that existed during 1967, were made to show the dissolved oxygen response to future variations in flow and waste loadings. Treatment efficiencies necessary to maintain an average dissolved oxygen concentration of 5.5 mg/l in the stream were estimated for the 1980, 2000 and 2020 years. A background level of 2 mg/l of BOD₅ was assumed.

The calculations indicate that, to meet an average dissolved oxygen level of 5.5 mg/l during low flow periods, between 94 and 98 percent of the BOD₅ will need to be removed and effluents aerated to 6 mg/l. To achieve these efficiency levels with existing technology, the municipalities, except Sherborn, would typically have to provide the equivalent of primary treatment, secondary treatment, coagulation, sedimentation, filtration, carbon adsorption and post-aeration. Effective chlorination is also necessary to control bacteria and viruses. These treatment methods would also provide a high level of phosphate removal with effluent phosphate concentrations on the order of 0.5 mg/l as P.

(2) Basis of Cost Estimates

The average annual costs have been compared for individual treatment plants versus alternate regional treatment plants to limit waste loads discharged to the amount necessary to maintain 5.5 mg/l dissolved oxygen in the stream during extreme low flow conditions and high river temperatures.

Treatment costs were taken from curves developed by Robert Smith, EPA, Cincinnati, Ohio. The curves present average costs on a national basis and are considered valid for the purpose of comparing treatment plant configurations. The treatment costs reflect both capital costs and costs of operation and maintenance. Operation of advanced waste treatment processes was assumed necessary

for only six months per year. Capital costs of treatment were amortized over 25 years at 4-5/8 percent interest. The annual cost of providing the necessary treatment is about twice the cost of secondary treatment alone.

Costs of interceptors were based on curves prepared by Bowe, Albertson and Walsh, Consultants, for towns in Suffolk County, New York. These costs compared favorably with interceptor costs compiled by Metcalf and Eddy, Consulting Engineers, Boston. Interceptor costs were amortized over 50 years at an interest rate of 4-5/8 percent.

As reported by Robert Smith, construction costs represent above 80 percent of the total bonded cost for plant construction. Therefore, construction costs were multiplied by a factor of 1.25 to allow for preliminary expenses such as administrative, engineering and legal fees, interest during construction and contingencies. All costs were adjusted to the June 1967 level.

(3) Costs of Alternatives

Types of alternatives considered and evaluated:

- *A comparison of individual treatment plants, regional treatment plants, and dual community configurations located on the Charles River for the communities of Milford, Bellingham, Franklin, Medway and Wrentham.
- *A comparison of individual treatment plants and regional and subregional plants for the communities of Norfolk, Millis, Medfield and Holliston.
- *A single regional treatment plant for all of the above communities.

Projections for Sherborn indicate that a sewerage system will not be required until about 1990. At that time, Sherborn will probably construct its own treatment plant because of the small load and distance from other Upper Charles River communities.

(a) Milford, Bellingham, Franklin, Medway and Wrentham

Of the first group of communities considered, Milford has a secondary treatment plant in need of rehabilitation. Franklin and Medway are now under orders of the Commonwealth of Massachusetts to construct and operate sewage treatment facilities by 1973 and 1972, respectively. Bellingham and Wrentham, as indicated by the projections, should construct a sewerage system in the near future.

For the five municipalities and also for four of them, excluding Milford, the following sewage treatment plant configurations have been considered:

1. Individual treatment plants from 1970 to 2020.
2. A regional treatment plant from 1970 to 2020.
3. Individual plants from 1970 to 1995, followed by a regional plant from 1995 to 2020.
4. Four dual municipality configurations for the 1970 to 1995 period consisting of:
 - a. Milford and Bellingham
 - b. Franklin and Medway
 - c. Bellingham and Franklin
 - d. Medway and Wrentham.

Tables E-16, E-17 and E-18 summarize the costs of providing the various treatment plant configurations.

During the initial construction phase (1970-1995) the average annual cost of constructing and operating individual treatment plants is approximately 10 percent less expensive than either a four-community or five-community regional plant. (Table E-16 and E-17) A dual community plant between Milford and Bellingham would have about the same total cost as individual plants constructed concurrently. A dual community plant between Medway and Wrentham is approximately 6 percent more expensive than individual plants.

Costs of the dual plant for Franklin and Medway are based on a Franklin plant on Mine Brook at the site of the existing plant about 3.5 miles from the mouth of the brook. The Medway plant was assumed to be along the Charles River, downstream of Populatic Pond (see Figure E-20). The cost of the dual plant included an interceptor to transport Franklin's waste from Mine Brook to the proposed dual plant location which is also below Populatic Pond.

Recently, the engineering consultant for Franklin has recommended that the town construct a new plant which would discharge to the Charles River one-half mile downstream of the Mine Brook confluence, at about the same cost as constructing the plant at the existing Mine Brook site. The proposed Franklin plant along the Charles River would be about two miles from the Medway plant. In light of this recent development the two towns should determine if a single plant could serve both communities.

From 1995 to 2020, the cost of construction and operation of a four-community regional treatment plant is about the same as that of constructing and operating individual plants.

TABLE E-16

CHARLES RIVER WATERSHED STUDY

Comparison of Average Annual Cost of Individual
versus Regional Systems for Milford, Bellingham,
Franklin, Medway and Wrentham

Secondary Treatment Plus Six Months Operation of
Coagulation, Sedimentation, Filtration, Carbon
Adsorption and Post Aeration to 6 mg/l Dissolved Oxygen

	<u>1970-1995</u>	<u>1995-2020</u>
Individual Treatment (1970-2020)	\$1,037,000	\$2,010,000
Regional Treatment (1970-2020)	1,130,000	2,288,000
Individual Treatment (1970-1995), Regional Treatment (1995-2020)	1,037,000	2,032,000

TABLE E-17

CHARLES RIVER WATERSHED STUDY

Comparison of Average Annual Cost of Individual
versus Regional Systems for Bellingham, Franklin,
Medway and Wrentham

Secondary Treatment Plus Six Months Operation of
Coagulation, Sedimentation, Filtration, Carbon
Adsorption and Post Aeration to 6 mg/l Dissolved Oxygen

	<u>1970-1995</u>	<u>1995-2020</u>
Individual Treatment (1970-2020)	\$711,000	\$1,450,000
Regional Treatment (1970-2020)	793,000	1,628,000
Individual Treatment (1970-1995), Regional Treatment (1995-2020)	711,000	1,462,000

TABLE E-18

CHARLES RIVER WATERSHED STUDY

Comparison of Average Annual Cost of Individual
versus Dual Community Systems - 1970-1995

Secondary Treatment Plus Six Months Operation of
Coagulation, Sedimentation, Filtration, Carbon
Adsorption and Post Aeration to 6 mg/l Dissolved Oxygen

	Individual	Dual Community
Milford and Bellingham	\$426,000	\$426,000
Franklin and Medway	463,000	568,000
Bellingham and Franklin	456,000	528,000
Medway and Wrentham	255,000	271,000

(b) Norfolk, Millis, Medfield and Holliston

The second regional configuration includes Norfolk, Millis, Medfield and Holliston. At the present time, Millis and Medfield have new secondary treatment plants. Both will be in need of expansion in the near future. The municipality of Norfolk will not need a sewage treatment plant until about 1985. Sources of waste in Norfolk include the Pondville Sanitarium and the Norfolk Prison, both of which discharge to the Stop River. The Norfolk Prison is presently under orders to build and operate a new secondary treatment plant. The Pondville Sanitarium has an efficient secondary treatment plant. Holliston is not on an implementation schedule, but projections indicate that sewerage facilities will be needed in the near future.

Treatment plant configurations that have been considered are as follows:

1. Individual treatment plants from 1970 to 2020.
2. A dual community plant consisting of Millis and Medfield from 1970 to 1995.
3. A tri-community plant consisting of Millis, Medfield and Holliston from 1970 to 1995.
4. A regional plant for the four communities between 1995 and 2020.

Cost estimates of these alternatives are presented on Table E-19.

These estimates show there would be a saving of approximately 6 percent if Millis and Medfield construct a joint treatment plant when these communities expand. Both communities now discharge into small brooks that drain to the Charles River less than a mile from each other. A tri-community plant consisting of Millis, Medfield and Holliston also compares favorably with individual plants.

Between 1995 and 2020 a regional treatment plant appears to be less expensive than individual plants.

(c) Single Regional Plant

From 1995 to 2020 the cost of constructing one regional treatment plant to handle the wastes of the nine communities (Sherborn not included) was compared to the cost of treating the waste at two treatment plants as discussed above. The average annual costs of each were essentially equal--\$2,970,000 for two regional plants

TABLE E-19

CHARLES RIVER WATERSHED STUDY

Comparisons of Average Annual Costs of Alternate
Treatment Systems

Norfolk, Millis, Medfield, Holliston

Secondary Treatment Plus Six Months Operation of
Coagulation, Sedimentation, Filtration, Carbon
Adsorption and Post Aeration to 6 mg/l Dissolved Oxygen

Period 1970 - 1995

Individual Treatment Plants

Norfolk	\$108,000 ¹	Medfield	\$175,000 ²
Millis	153,000 ²	Holliston	125,000

Dual Treatment Plant - Millis and Medfield

Dual Plant	\$311,000
Individual Plants	328,000

Tri-Community Plant - Millis, Medfield and Holliston

Tri-Community Plant	\$449,000
Dual Plant (Millis and Medfield), Individual Plant (Holliston)	436,000
Individual Plants	453,000

Period 1995 - 2020

Individual Treatment Plants	\$1,128,000
Regional Treatment Plant	978,000

1. Costs reflect those of institutions within Norfolk. Town of Norfolk does not require sewerage system at present time.
2. Cost of expanding existing sewage treatment plant.

and \$2,960,000 for one regional plant. The average annual cost of constructing and operating one regional plant to handle the wastes of eight communities, Milford not included, was \$2,560,000 compared to an average annual cost of \$2,400,000 to construct and operate two regional plants.

A more detailed cost breakdown of all alternatives considered is presented in Attachment ED.

(d) Summary

All combinations investigated during the 1970-1995 time frame, with three exceptions, show individual treatment plants to be more economical than a regional plant. The first exception is a dual plant serving Millis and Medfield which would be slightly less expensive than individual systems. The other exceptions are a tri-community plant serving Millis, Medfield and Holliston, and a dual plant for Milford and Bellingham. The latter two systems are essentially equal to individual plants.

In many cases, however, the costs were within 10 percent of each other. These combinations that vary within 10 percent (considered economically equivalent) are as follows:

1. Individual plants versus a regional plant for Milford, Bellingham, Franklin, Medway and Wrentham.
2. Individual plants versus a dual community plant for Milford and Bellingham.
3. Individual plants versus a dual community plant for Medway and Wrentham.
4. Individual plants versus a dual community plant for Millis and Medfield.
5. Individual plants versus a tri-community plant for Millis, Medfield and Holliston.

Combinations that had a greater than 10 percent variance for the 1970 to 1995 period were as follows:

1. Individual plants versus a regional plant for Bellingham, Franklin, Medway and Wrentham. (Individual plants 11 percent less expensive.)
2. Individual plants versus a dual community plant for Franklin and Medway. (Individual plants 23 percent less expensive.)

3. Individual plants versus a dual community plant for Bellingham and Franklin. (Individual plants 16 percent less expensive.)

(4) Other Considerations

In those circumstances where the costs of alternate treatment plant configurations are about the same, other considerations will play a deciding role in choosing the alternative, particularly where decisions will be needed in the immediate future. Some of the major considerations are as follows:

(a) Regional treatment plants would remove waste discharges from tributary streams and the upper reaches of the Charles River, but also could deplete flows to such an extent that desired uses may be curtailed in the affected reaches.

(b) Regional treatment plants require less land and physical plant than a series of individual treatment plants. Aesthetic benefits associated with the fewer treatment plants may be a factor.

(c) Larger treatment plants generally are better able to absorb changing characteristics and volume of wastes being treated.

(d) Timing of construction between communities and site selection could make it difficult to implement a regional facility.

(e) Cost analyses for the 1995 to 2020 time frame may influence immediate decisions.

In addition to the above considerations, the communities in the Upper Charles River Watershed should form a regional sewerage district. Advantages commonly attributable to regional treatment plants may also be possible if individual facilities are operated by a single management authority such as:

(a) Increased efficiency of operation because of ability to employ highly qualified personnel such as process specialists, biologists, chemists and electrical and instrumentation technicians.

(b) Ability to correct operational and maintenance problems more quickly because of specialists, availability of central maintenance facilities and a large spare parts inventory.

(c) May relieve local communities of the problems associated with administration, operation and maintenance of a complex treatment facility.

d. Combination of Low Flow Augmentation and Advanced Waste Treatment

Curves have been developed for Charles River zones which show average annual reductions in treatment costs over a fifty-year period as a result of providing various levels of flow and augmentation amounts. The flow amounts shown on the curves would be needed during the warmest months, July and August (assumed river temperature of 30°C). During periods when river temperatures are lower, for the same level of treatment, lesser amounts of flow would be required to maintain adequate dissolved oxygen concentrations in the stream. Therefore, the ratios of flows required at 20°C river temperatures (May and October) and 25°C (June and September) to those required at 30°C for the same waste load have been calculated to establish a flow regime for each zone. Flow regimes, once established, may then be used to determine and compare the costs of reservoir storage with corresponding treatment cost reductions for purposes of project formulation.

Preliminary investigations made by the Corps of Engineers and the Soil Conservation Service indicate that flow augmentation sites on Mine Brook and Bogastow Brook may provide a net savings in the treatment costs of sources in Franklin on Mine Brook, and in Holliston on Bogastow Brook.

The curves of average annual reductions in treatment costs over 50 years versus flow augmentation amounts and the flow regime developed for each zone along with a description of the development of curves and flow regimes and their method of application are presented in Attachment EE.

e. Disposal of Wastes Outside of Watershed

The transportation of wastes outside of the watershed with treatment and disposal at the MDC sewage plant at Nut Island was also investigated as a method of improving the quality of waters of the Charles River Watershed.

One advantage of this alternative is that waste discharges would be removed from the Upper Charles River, thus assuring a good quality water. In addition aesthetic benefits would also accrue by eliminating treatment plants and associated lands from the watershed.

On the other hand, the depletion of flows in the river could curtail desired uses, and transporting wastes out of the watershed would be expensive.

For example, the cost of transmitting wastes from the Upper Charles River communities to the MDC sewage treatment plant at Nut Island, including the communities' share of the capital and operation and maintenance costs at the Nut Island treatment plant are estimated to

be \$2,125,000 annually during the 1970 to 1995 time period, and \$4,618,000 annually during the 1995-2020 period. The most economical combination of treatment and disposal within the watershed is \$1,590,000 annually for the 1970 to 1995 time period, and \$3,000,000 annually for the 1995 to 2020 period.

f. Subsurface Disposal

If the soil has good permeability, subsurface disposal of wastes after secondary treatment and chlorination can offer an economical way of meeting water quality goals.

There are two common methods of subsurface disposal; namely, direct injection into the groundwater through recharge wells, and spreading or distributing the waste on the ground surface and allowing it to seep into the soil. The injection method has several disadvantages over spreading. High levels of treatment may be required prior to injection to avoid clogging of the recharge well. The removal of pollutants from the waste as it travels through the soil to the groundwater by the spreading method is negated by direct injection. Unless land costs are extremely high, groundwater injection is usually more expensive than spreading.

Disadvantages of waste water spreading are the relatively high land requirements and possible operational problems during periods of high water table and during the winter months.

Percolation through the ground has been shown to be an effective mechanism for the removal of pollutants from wastewater. Studies at wastewater reclamation projects have shown that vertical percolation of wastewater through relatively short distances is effective in removing bacteria and virus, BOD₅, suspended solids and phosphate ion.

Geologic studies of the Charles River Watershed are being undertaken by the U.S. Geological Survey. Preliminary results indicate the existence of many sand and gravel lenses near the river bank that may be suitable for wastewater spreading.

Wastewater spreading should be considered by the Charles River communities. Prior to its use, detailed engineering investigations and extensive borings and percolation tests will be required at proposed spreading sites.

A more detailed description of the subsurface disposal method and cost comparisons with advanced waste treatment are shown in Attachment EF.

g. Disposal of Waste to Wetlands

A major recommendation of the Charles River Watershed Study will be to acquire and preserve approximately 8,500 acres of wetlands which provide natural flood control storage. Most of the wetlands, about 7,500 acres, lie above the Charles River Village gage.

In addition to flood control benefits, it may be possible for Charles River towns to utilize the marshes as a means of waste disposal. Following secondary treatment and chlorination, a town's sewage effluent may be distributed over the wetland. As the waste travels through the wetland, nutrients and organics would be used by plants and additional suspended materials would be removed by settling. The result would be the maintenance of water quality standards in the stream with substantial savings in treatment costs. Periods of high runoff when this method of disposal may not be effective correspond to the time when operation of advanced treatment processes are also not needed.

Possible disadvantages may be short circuiting effects which could cause carryover of nutrients to the stream and over-enrichment of the wetlands. Prior to its use, detailed studies of wetland hydrology, rates of nutrient uptake by plants, and the possible problems of over-enrichment should be investigated.

This method of waste disposal should be considered by the Charles River communities. Small scale demonstration projects to determine the feasibility of disposal to the wetlands should be a first step.

h. In-Stream Aeration

As previously mentioned, in the future waste contributors should provide post-aeration as a normal treatment process. During low flow periods, the river flow will be predominantly waste effluent. In addition to high levels of BOD₅ removal, post-aeration is considered necessary to assure that adequate dissolved oxygen levels are maintained in the stream below waste outfalls.

As an alternate to post-aeration at the treatment plant, oxygen may also be introduced directly to the stream by the installation of floating mechanical aerators or diffused air systems. However, post-aeration probably has several advantages over in-stream aeration. Because of the relatively constant flows and waste effluent characteristics at a treatment plant, mechanical aerators may be designed to achieve higher efficiencies of aeration than in-stream aerators. Aeration devices located at the treatment plant can be operated and maintained by plant personnel much more easily than in-stream aerators, especially when more than one waste source contributes to the

same oxygen sag. In addition, aerators located in the stream could interfere with boating, can be displeasing to the eye, and may present a safety hazard to inquisitive youngsters.

Recently, a consultant firm has proposed that a series of cascades be placed in the Charles River below the Milford secondary sewage treatment plant to supply oxygen to the stream to relieve the nuisance conditions that presently occur, and also to provide added aeration potential when Milford constructs necessary additional treatment facilities. Cascades are inexpensive to construct and install, and require little maintenance. Full advantage should be taken of the aeration afforded by devices such as cascades or weirs, either in-stream or in the waste effluent channel, to reduce the cost of mechanical post-aeration.

i. Methods to Reduce Effects of Non-Point Sources of Pollution

(1) Urban Runoff

Pollutants added to a stream from urban runoff can, at times, be significant. As communities grow, the problems associated with urban runoff may become more severe unless the communities are aware of the problem and counteract it.

To prevent illegal discharges of domestic or industrial wastes to storm water sewers, comprehensive ordinances relative to sewer use should be established and strictly enforced. An effective sewer inspection and maintenance program should also be implemented by each community.

A particularly objectional problem affecting the Charles River is the oils that are discharged from a number of diffuse sources. Frequent inspection of service stations and other sources of waste oil should be made to insure that "grease-traps", which are designed to collect the oil so that it is not discharged to the storm drains, are functioning properly. Methods must be developed to adequately dispose of or reprocess waste oils.

Litter, dirt, dust, oils, etc. that accumulate on the ground surface can best be controlled by litter prevention and removal of such materials before they are washed to nearby water-courses. Urban beautification programs should be implemented within each community. In addition to aesthetically enriching the community, the amount of pollutants added to nearby streams would be greatly reduced. Community programs should include public education, beautification of private property, the placement of sufficient litter containers, frequent collections of trash and garbage, frequent street cleaning, effective anti-littering enforcement, and frequent cleaning of catch basins.

As communities expand and are required to construct new storm drainage systems, careful design may reduce the effects of urban runoff. For example, storm outlets should not be allowed to discharge to high use areas such as recreational ponds or at particularly scenic reaches of streams. The total number of storm drain outlets should be minimized in the event that treatment of storm drainage becomes necessary.

Recently, the American Public Works Association conducted a detailed study of the urban runoff problem. The results of the investigation and suggested control measures presented in greater detail than described above are contained in the report entitled Water Pollution Aspects of Urban Runoff. This reference should be obtained and used by local public works and planning agencies with a role in urban beautification and sewerage works.

Once control measures described above are instituted, additional means of abating pollution from urban runoff may be required to achieve desired uses of the stream. It may be necessary to remove additional pollutants such as bacteria, oil, suspended materials, etc., by treatment either within the storm drainage system or by treating the stream itself.

(2) Sanitary Landfills

Compliance with regulations administered by the Massachusetts Department of Public Health would reduce pollution from sanitary landfills. These regulations prohibit the location of a sanitary landfill in areas subject to flooding, in areas where the maximum ground water elevation is less than four feet from the lowest point of refuse deposition, or within 60 feet horizontally of any surface waters.

Refuse disposal sites that are in violation of the above criteria should be phased out as soon as possible and measures should be taken to prevent further pollution at these sites. If the regulations are strictly followed and sanitary landfills are properly operated and maintained, pollution of the Charles River should be significantly reduced or eliminated from this source.

7. ENVIRONMENTAL RELATIONSHIPS

The primary goal of the foregoing water quality management measures is to meet quality standards in the Charles River, and to make possible the water uses provided in those standards. When fully implemented, the river can provide an attractive setting for a wide range of recreation water uses including boating, swimming and fishing, and at the same time fulfill its more mundane but, nevertheless, important role of receiving, assimilating and transporting treated wastewater discharges.

More than a successful water quality program is needed, however, to achieve full potential. Planning, development and management in related water resource and land use areas is essential to obtain full benefits. Actions in these areas can either enhance or degrade the water use; and, conversely, actions geared to the creation of better water quality also can enhance or inhibit other goals. To assess, then, the true value of the water quality program, it would be necessary to examine it in terms of its interaction with other forces in the basin, both planned and unplanned, in an effort to determine its net value and impact on society and on the basin's surroundings.

A total environmental analysis of this type is not easy. There are too many unknowns and unpredictable variables to expect complete answers. Even if it were possible to predict with some degree of certainty the economic, social and environmental consequences of alternate courses of action, valid differences of opinion on priorities and goals would require that final choices be made in the political forum. Despite the impossibility of arriving at firm recommendations, it is important to recognize that water quality is not an end in itself; and that some discussion of its relationship with other environmental factors is needed to place it in perspective.

First, actions aimed at improving water quality inevitably will have side effects. Some examples of these are discussed below:

A necessary part of a treatment plant construction program is the extension of existing sewerage systems and the consequent abandonment of on-site subsurface disposal systems. In many cases, these systems are causing local health and nuisance problems, and, in other cases, they are functioning adequately. The net effect is to collect a large volume of sewage where it can be economically treated rather than to dispose of it in the ground near its source. In some respects, the latter course is preferable, because it avoids the concentrated problems associated with treatment plants and their impact on the receiving water's quality. Unfortunately, individual disposal systems become less adequate as areas become more densely populated, and the cost of collection, treatment and river impact are one of the prices of urbanization.

Extension of major trunk and interceptor sewers to areas of predicted growth may itself have a causal effect on long-term population distribution and land use. Community planners and developers are likely to seek out those areas where utility services are readily available. Sewer construction, if not planned along with other services and needs, can have a disproportionate influence on zoning, transportation facilities and community growth patterns.

It has been said the natural color of the Charles River is like tea, and that it will always look dirty, regardless of wastewater treatment programs. The kind of wastewater treatment processes, however, that are proposed for the Charles River Basin will produce an effluent of higher quality in some respects than the natural river flow. It will have less natural color, artificial color and turbidity than the river now has. As these treated waste flows increase and become a larger fraction of the total flow, the appearance of the water in the river will improve. This will increase over a period of time, and will be most pronounced during dry weather periods when the natural flow contribution is small.

The location of treatment plants will affect the low flow hydrology of the river since wastewater will provide much of the flow in the river during dry periods. In the extreme, it is possible to correct a water quality problem in a brook by diverting sewage to another treatment location. But during a critically dry period, this might also eliminate most of the brook flow and any of its water uses, whatever they might be, for a brief time.

Treatment plant construction, operation and maintenance will also have environmental consequences. Siting and architecture have aesthetic impact. Methods chosen for the final disposal of sludge can influence the quality of the groundwater, air and land resources. Where alternates exist, both market place economics and environmental costs should be weighed.

Low flow augmentation, if used as an alternate to advanced waste treatment, has several effects on the downstream watercourse. Among these are: 1) additional dilution of non-degradable wastes, 2) increased river depths, 3) higher stream velocities, 4) greater flow at all downstream locations for better assimilation of treated waste regardless of unforeseen loading conditions and patterns, and 5) dilution of waste emanating from diffuse sources that are not subject to collection and treatment.

At the reservoir projects built for flow augmentation and other purposes, environmental changes will also occur. Man-made structures, highways and utilities would be removed, and in some cases relocated, and the existing terrain and stream would be replaced by a pond or lake and a dam structure. Adverse aesthetic effects, most pronounced during drought periods, may also occur as a result of drawdown of pool levels.

Improvement of Charles River water quality, coupled with increased public use, can trigger further actions resulting in even higher standards and higher levels of water quality. The present standards were established after public hearings and specific legislative and administrative actions, and now have the force of law. While they necessarily must serve as the fundamental goal of this study and recommendations arising from it, it would be naive to assume they will be unchanging. Because of increased use and public awareness, periodic review of the standards will be essential to insure they meet the requirements and needs of a changing human environment. These future changes, together with improved control methods and management methods, will lead to even further environmental changes.

The environmental effect of the water quality program, acting in combination with other water resource and land use programs, is undoubtedly even more far reaching than the side effects resulting from water quality control actions alone.

Water supply programs, for example, interact with water quality programs in several ways. Where the river serves as either an industrial or municipal supply source, the need for water supply treatment is dependent on the basic river water quality. Also, the choice of supply sources will affect the low flow hydrology and waste assimilative capacity of the river. When natural river flow is diverted for water supply, when ground water sources near the river are used, and when wastewater after use and treatment is not returned directly to the river, river flows will tend to decrease. When a supply is imported from outside the basin and when supply reservoirs within the basin release water from storage, river flows will tend to increase. All of the above factors will be operating within the basin as time goes on, and will have a bearing on the river's flow and its capacity to dilute, assimilate and transport waste.

Another program related to pollution cleanup will be the effort to improve the river's fishery. The success of the plan to restore the American shad and alewives by replacing certain fish ladders and installing new ones at a number of dams will hinge on not only water quality, but will also depend on other ecological and management elements.

The MAPC has recommended studies be undertaken to develop an inter-connected system of bridle paths, walking and bicycle trails. Launching places for boats are proposed at various points. MAPC also urges that land be acquired for public use or to be left in its natural state, particularly the natural valley storage areas of wetlands. The Massachusetts Department of Natural Resources favors a recreation corridor along the Charles. It recommends that 10,000 acres be protected through a variety of holding and restrictive measures. The Corps of Engineers is considering a proposal to preserve 8,500 acres of natural valley storage areas for flood control

and other purposes, and the Soil Conservation Service is evaluating possible conservation pool development and potential conservation areas within the basin.

These and other public and private developments will be strengthened by better water quality. Careful management of land and water uses, conversely, will encourage better water quality control and management practices. Both reinforce each other and are essential for use and protection of the natural resources.

A successful cleanup which makes the water more attractive for use and development, in conjunction with the pressure of an expanding population, poses a difficult problem. Poorly planned and supervised residential building, motels, commercial development and public areas, and lack of adequate and well controlled access could thwart the very uses and benefits sought in establishing the water quality standards. The induced developments may create more pollution in the form of treated discharges, poorly sited septic tanks, dumps, debris and oil, either violating the standards or making it more costly to achieve them.

Community, State, Federal and private interests are now being forced to address this major environmental issue. Most can agree that a balanced and well coordinated program is needed with proper emphasis placed on preservation, conservation, utilization and economic development. Divergent interests and values, nevertheless, make it difficult to accomplish this on a mile-by-mile and acre-by-acre basis. In the last analysis, achievement of water quality standards will be an essential and important step in maintaining environmental quality. The wisdom with which other land and water use factors can be accommodated and managed will play an even more important role in determining the future landscape and atmosphere of the Charles River Basin.

8. SUMMARY AND CONCLUSIONS

1. At the present time, reaches of the Charles River and tributary streams are seriously degraded by discharges of untreated or inadequately treated wastes. In 1968 approximately 3,100 pounds of BOD₅ were discharged daily to the stream from known sources of waste. The raw waste load before treatment was approximately 8,300 pounds per day. Pollutants are also added to the stream as a result of storm water runoff, particularly in the highly urban middle and lower sections of the watershed.

2. The Commonwealth of Massachusetts' water quality standards for the Charles River include three essentials. They reflect a public consensus as to desired uses for each stretch of water, they establish critical limits of the amount of various pollutants allowed in the waters so that the desired uses may be realized, and they provide an implementation schedule for the construction by 1973 of waste treatment facilities required to meet the water quality criteria adopted. The Charles River Classification is shown on Table E-20 and Figure E-5. Water quality criteria appear in Attachment EA.

3. At the present time, major sections of the Charles River do not meet the allowable criteria established for dissolved oxygen, coliform bacteria and nutrients, such as phosphate and ammonia. Legitimate uses of the stream are prevented or reduced.

4. Attainment of the standards without delay is an essential step in gaining full use of the watershed's potential.

5. Rapid growth is expected in the area, particularly in the upper reaches of the watershed. Estimated raw waste loads to the Charles River Watershed from those communities, including industrial contributions, are expected to be 15,000, 29,000 and 52,000 pounds per day of BOD₅ in 1980, 2000 and 2020, respectively.

6. Projected waste flows from the same communities are 11.7 cfs, 26.4 cfs and 53.2 cfs in 1980, 2000 and 2020, respectively. The present seven-day low river flow with a ten year recurrence interval measured at the Charles River Village gage, which is downstream of all projected waste discharges, is only 12 cfs. In the future, therefore, during low flow periods, a significant portion of the river flow will be made up of waste discharges.

7. To satisfy water quality needs as expressed by the water quality standards, advanced waste treatment processes beyond the secondary treatment level are necessary. As population increases, demands for even higher water use can also be anticipated. Further engineering studies will be needed to determine the final design of these facilities, and the extent to which low flow augmentation, industrial plant process changes, and other control measures are to be used.

TABLE E-20

CHARLES RIVER WATERSHED STUDY

Charles River Watershed Classification

Boundary	River Miles	Present Use	Anticipated Future Use	Present Condition	Classification
The Charles River from its source to Dilla Street, Milford	80.1-76.5	Water supply	Water supply	A	A
The Charles River from Dilla Street, Milford to Main Street, Milford	76.5-75.2	Bathing Fish & wildlife propagation Fishing	Same	B	B
The Charles River from Main Street, Milford to Bridge Street, Dover	75.2-44.7	Recreational boating Fish & wildlife propagation Fishing Assimilation	Same	D & C	C
The Charles River from Bridge Street, Dover to Watertown Dam, Watertown	44.7-9.8	Recreational boating Fish & wildlife propagation Fishing Assimilation	Same and bathing	D & C	B
The Charles River from Watertown Dam, Watertown to the Charles River Basin Dam in Boston	9.8-1.2	Recreational boating Fish & wildlife propagation Fishing Assimilation	Same	D & C	C
Farm Pond, Sherborn	--	Recreation	Recreation	B	B
All other streams in the Charles River Watershed unless denoted above	--	--	--	-	B

Commonwealth of Massachusetts, Water Resources Commission, Division of Water Pollution Control

8. For purposes of comparison in evaluating the need for flow augmentation, a minimum treatment level consisting of secondary treatment and six months' operation of a coagulation and sedimentation process to remove phosphate was assumed. In addition to nutrient removal, approximately 90 percent of the BOD_5 is removed by this type of treatment.

9. To maintain an average dissolved oxygen level of 5.5 mg/l in the Charles River and tributaries only with a minimum level of treatment, theoretical augmentation flows during the critical summer months would have to be as high as 165 cfs by 1995 and 390 cfs by 2020. This augmentation would be in addition to the minimum base flow, plus the flow corresponding to waste discharges. All augmentation water was assumed to contain dissolved oxygen levels equivalent to 88 percent saturation.

10. Without any flow augmentation, to meet an average dissolved oxygen level of 5.5 mg/l during low flow periods, by 1980 the communities would have to remove between 94 and 98 percent of the BOD_5 and effluents would have to be aerated to 6 mg/l. To achieve these efficiency levels with existing technology, the municipalities, except Sherborn, would typically have to provide the equivalent of primary treatment, secondary treatment, coagulation, sedimentation, filtration, carbon adsorption and post-aeration.

11. Assuming no flow augmentation, the average annual costs have been compared for individual treatment plants versus alternate regional treatment plants to provide adequate dissolved oxygen levels in the stream. Generally, results indicate for the 1970 to 1995 period, individual plants are slightly more economical than regional alternatives with the possible exception of a single plant serving Millis and Medfield, and a single plant serving Franklin and Medway. During the 1995 to 2020 time frame, a regional plant serving Norfolk, Millis, Medfield and Holliston would save approximately 13 percent. In many cases, however, the costs of alternatives are within 10 percent of each other and are considered economically equivalent. Average annual costs are on the order of \$1,600,000 for the 1970 to 1995 time frame, and \$3,000,000 during the 1995 to 2020 period. The costs are at an interest rate of 4-5/8 percent. They include costs of operation and maintenance. Operation of advanced treatment processes was assumed necessary for only six months per year.

12. The technology of advanced waste treatment is improving rapidly. While the costs and processes used herein are considered valid for comparing alternate water quality control measures for general planning purposes, the actual cost of future construction and operation may be reduced as new or better processes and operating procedures are developed.

13. In those circumstances where the costs of alternate treatment plant configurations are about the same, other considerations will play a deciding role in choosing the alternative, particularly where decisions will be needed in the immediate future. Some of the major considerations are as follows:

a. Regional treatment plants would remove waste discharges from tributary streams and the upper reaches of the Charles River, but also could deplete flows to such an extent that desired uses may be curtailed in the affected reaches.

b. Regional treatment plants require less land than a series of individual treatment plants. Aesthetic benefits associated with the fewer treatment plants may be a factor.

c. Larger treatment plants generally are better able to absorb changing characteristics and volume of wastes being treated.

d. Timing of construction between communities and site selection could make it difficult to implement a regional facility.

14. Curves have been prepared which indicate the savings in the cost of advanced waste treatment, that is, beyond the assumed minimum treatment level, as a result of providing intermediate levels of flow augmentation for various zones on the Charles River and tributary streams. It may be possible to achieve a net savings in treatment plant costs by providing flow augmentation. Preliminary investigations made by the Corps of Engineers and the Soil Conservation Service indicate that flow augmentation sites on Mine Brook and Bogastow Brook may provide a net savings in the treatment costs of sources in Franklin on Mine Brook, and in Holliston on Bogastow Brook. In addition to reducing treatment costs, low flow augmentation can be used to reduce the effect of non-point sources of pollution in the river.

15. Cost analyses have been made of collecting the wastes from the watershed, transporting them to the MDC treatment plant at Nut Island, and expanding the Nut Island facility. Average annual costs of this method of disposal, which include operation and maintenance costs, are \$2,120,000 for the 1970 to 1995 time period, and \$4,620,000 during the 1995 to 2020 period. Disposal of all wastes outside of the watershed is more expensive than treatment and disposal within the watershed, could seriously deplete flows in the Charles River, and, therefore, is considered impractical. However, on an individual basis it may be economical for a community, particularly one that borders the MDC sewerage system, to join the MDC.

16. Sursurface disposal of chlorinated secondary waste effluent may offer an economical means of meeting water quality goals and should be considered by the Upper Charles River communities. Preliminary studies of the U.S. Geological Survey indicate that sand and gravel lenses suitable for wastewater spreading may exist. Prior to such disposal, detailed borings, percolation studies and cost estimates would be required.

17. A major recommendation of the Charles River Watershed Study will be to acquire and preserve approximately 8,500 acres of wetlands, of which 7,500 lie above the Charles River Village gage. It may be possible to use the marshes as a means of waste disposal by distributing secondary treated effluent over the wetland. As the waste travels through the wetland, nutrients and organics would be used by the plants, and additional suspended materials would be removed by settling. Prior to its use, detailed studies of wetland hydrology, rates of nutrient uptake by plants, and the possible problems of over-enrichment and short circuiting should be investigated. Small scale demonstration projects to determine the feasibility of disposal to the wetlands should be a first step.

18. Post-aeration is considered necessary to assure that adequate dissolved oxygen levels are maintained in the stream below outfalls. Full advantage should also be taken of the aeration afforded by devices such as cascades or weirs, either in-stream or in the waste effluent channel, to reduce the cost of mechanical post-aeration.

19. The communities in the Upper Charles River Watershed should form a regional sewerage district. Treatment plants that will be needed in the future, whether they serve an individual community or a regional area, will be complex and require highly trained personnel. The ability to employ highly qualified personnel is enhanced under a single authority. Also operational and maintenance problems may be corrected more quickly because of the greater variety of specialists and availability of central maintenance facilities and a large spare parts inventory.

20. To reduce the adverse effects of urban runoff, watershed towns, where necessary, should institute and enforce comprehensive sewer use ordinances, establish effective sewer inspection and maintenance programs, and implement community beautification programs.

21. Compliance with State regulations would reduce pollution from sanitary landfills. In those communities where pollution from solid waste disposal now occurs, corrective measures should be taken in accord with implementation schedules established by the Commonwealth of Massachusetts.

22. It is important that the water-related land use plan that is developed as part of the Charles River Watershed Comprehensive Study be closely coordinated with the achievement of water quality standards to insure that the desired uses of the waters can be fully realized.

23. Water quality standards are not static. They should be continuously evaluated and upgraded to reflect changes in public and private interests, technology and financial resources.

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ATTACHMENT EA

VELOCITY-DISCHARGE RELATIONSHIPS

CHARLES RIVER AND TRIBUTARIES

ATTACHMENT EA

CHARLES RIVER WATERSHED STUDY

Velocity-Discharge Relationships

CHARLES RIVER REACHES

Reach River Miles	From - To	Velocity-Discharge Equation	Average Q in Reach vs. Q at Charles River Village Gage
75.2-73.4	Main Street Bridge, Milford to Milford Sewage Treatment Plant	$v = 0.086 Q^{0.894}$	$Q = 0.04 Q_{crv}$
73.4-72.3	Milford Sewage Treatment Plant to Hartford Avenue Bridge, Bellingham	$v = 0.071 Q^{0.894}$	$Q = 0.05 Q_{crv}$
72.3-70.3	Hartford Avenue Bridge, Bellingham to Box Pond Dam, Bellingham	$v = 0.00090 Q^{0.965}$	$Q = 0.06 Q_{crv}$
70.3-66.4	Box Pond Dam, Bellingham to above No. Bellingham Dam	$v = 0.042 Q^{0.767}$	$Q = 0.09 Q_{crv}$
66.4-66.2	Above No. Bellingham Dam to No. Bellingham Dam	$v = 0.00068 Q^{1.00}$	$Q = 0.11 Q_{crv}$
66.2-65.4	No. Bellingham Dam to above Caryville Dam	$v = 0.30 Q^{0.776}$	$Q = 0.12 Q_{crv}$
65.4-64.7	Above Caryville Dam to Caryville Dam	$v = 0.00094 Q^{0.990}$	$Q = 0.13 Q_{crv}$
64.7-64.3	Caryville Dam to Hopping Brook	$v = 0.046 Q^{0.560}$	$Q = 0.13 Q_{crv}$
Hopping Brook River Mile = 64.3; Drainage Area = 11.5 sq. mi.		-	$Q = 0.05 Q_{crv}$
64.3-63.2	Hopping Brook to Mine Brook	$v = 0.035 Q^{0.560}$	$Q = 0.20 Q_{crv}$
Mine Brook River Mile = 63.2; Drainage Area = 15.7 sq. mi.		-	$Q = 0.08 Q_{crv}$

ATTACHMENT EA (Continued)
CHARLES RIVER REACHES

Reach River Miles	From - To	Velocity-Discharge Equation	Average Q in Reach vs. Q at Charles River Village Gage
Chicken Brook River Mile = 63.0; Drainage Area = 7.0 sq. mi.		-	$Q = 0.03 Q_{crv}$
63.2-57.6	Mine Brook to Mill River	$v = 0.027 Q^{0.560}$	$Q = 0.34 Q_{crv}$
Mill River River Mile = 57.6; Drainage Area = 16.3 sq. mi.		-	$Q = 0.08 Q_{crv}$
57.6-56.1	Mill River to Baltimore Street Bridge, Millis	$v = 0.073 Q^{0.706}$	$Q = 0.50 Q_{crv}$
56.1-51.8	Baltimore Street, Millis to Stop River	$v = 0.011 Q^{0.902}$	$Q = 0.52 Q_{crv}$
Stop River River Mile = 5.8; Drainage Area = 17.1 sq. mi.		-	$Q = 0.08 Q_{crv}$
51.8-50.3	Stop River to above Bridge Street Bridge, Millis	$v = 0.0080 Q^{0.902}$	$Q = 0.62 Q_{crv}$
50.3-49.8	Above Bridge Street Bridge, Millis to below Railroad Bridge	$v = 0.0074 Q^{0.902}$	$Q = 0.63 Q_{crv}$
49.8-48.4	Below Railroad Bridge to Bogastow Brook	$v = 0.0072 Q^{0.902}$	$Q = 0.66 Q_{crv}$
Bogastow Brook River Mile 48.4; Drainage Area = 25.5 sq. mi.		-	$Q = 0.13 Q_{crv}$
48.4-47.5	Bogastow Brook to above Main Street Bridge, Medfield	$v = 0.0063 Q^{0.902}$	$Q = 0.82 Q_{crv}$
47.5-39.4	Above Main Street Bridge, Medfield to Waban and Fuller Brooks	$v = 0.0060 Q^{0.902}$	$Q = 0.88 Q_{crv}$
Waban and Fuller Brooks River Mile = 39.4; Drainage Area = 16.1 sq. mi.		-	$Q = 0.08 Q_{crv}$

ATTACHMENT EA (Continued)
CHARLES RIVER REACHES

Reach River Miles	From - To	Velocity-Discharge Equation	Average Q in Reach vs. Q at Charles River Village Gage
39.4-38.2	Waban and Fuller Brooks to Charles River Bridge, Needham	$v = 0.0056 Q^{0.902}$	$Q = 0.98 Q_{CRV}$
38.2-34.5	Charles River Bridge, Needham to Charles River Village Gage	$v = 0.00055 Q^{1.00}$	$Q = 0.98 Q_{CRV}$
34.5-32.9	Charles River Village Gage to Chestnut Street Bridge, Needham	$v = 0.028 Q^{0.710}$	$Q = 1.00 Q_{CRV}$
32.9-26.5	Chestnut Street Bridge, Needham to Mother Brook	$v = 0.0068 Q^{0.660}$	$Q = 1.03 Q_{CRV}$
Mother Brook River Mile = 26.5; Diversion			
26.5-22.1	Mother Brook to Kendrick Street Bridge, Needham	$v = 0.0072 Q^{0.660}$	$Q = 0.95 Q_{CRV}$
22.1-20.2	Kendrick Street Bridge, Needham to Silk Mill Dam	$v = 0.0071 Q^{0.770}$	$Q = 0.97 Q_{CRV}$
20.2-20.0	Silk Mill Dam to Metropolitan Circular Dam	$v = 0.00090 Q^{1.00}$	$Q = 0.98 Q_{CRV}$
20.0-18.9	Metropolitan Circular Dam to Rosemary Brook	$v = 0.120 Q^{0.592}$	$Q = 0.98 Q_{CRV}$
Rosemary Brook River Mile = 18.9; Drainage Area = 3.4 sq. mi.			
18.9-17.9	Rosemary Brook to Newton Lower Falls Dam	$v = 0.130 Q^{0.578}$	$Q = 0.97 Q_{CRV}$
17.9-14.7	Newton Lower Falls Dam to Stony Brook	$v = 0.00023 Q^{1.31}$	$Q = 1.00 Q_{CRV}$
Stony Brook (Waltham) River Mile = 14.7; Drainage Area = 23.6 sq. mi.; Diversion			
14.7-12.6	Stony Brook to Moody Street Dam	$v = 0.00016 Q^{0.918}$	$Q = 1.09 Q_{CRV}$

ATTACHMENT EA

CHARLES RIVER WATERSHED STUDY

Velocity-Discharge Relationships

CHARLES RIVER TRIBUTARIES

Reach River Miles	From - To	Velocity-Discharge Equation	Average Q in Reach vs. Q at Charles River Village Gage
<u>Mine Brook R.M. 63.2</u>			
7.2-4.1	Grove Street Bridge, Franklin to Grove Street Bridge, (Lower) Franklin	$v = 0.14 Q^{0.53}$	$Q = 0.03 Q_{crv}$
4.1-3.4	Grove Street Bridge, (Lower) Franklin to Franklin Sewage Treatment Plant	$v = 0.11 Q^{0.53}$	$Q = 0.05 Q_{crv}$
3.4-0.0	Franklin Sewage Treatment Plant to Confluence	$v = 0.092 Q^{0.53}$	$Q = 0.07 Q_{crv}$
<u>Mill River R.M. 57.6</u>			
5.5-3.7	Franklin Street Bridge, Wrentham to above Norfolk-Franklin Boundary	$v = 0.084 Q^{0.54}$	$Q = 0.05 Q_{crv}$
3.7-0.0	Above Norfolk-Franklin Boundary to Confluence	$v = 0.068 Q^{0.54}$	$Q = 0.08 Q_{crv}$
<u>Stop River R.M. 51.8</u>			
7.0-6.7	Dedham Street Bridge, Norfolk to Pondville Sanitarium, Norfolk	$v = 0.48 Q^{0.54}$	$Q = 0.01 Q_{crv}$
6.7-3.4	Pondville Sanitarium, Norfolk to Norfolk Prison Sewage Treatment Plant	$v = 0.21 Q^{0.54}$	$Q = 0.05 Q_{crv}$
3.4-0.0	Norfolk Prison Sewage Treatment Plant to Confluence	$v = 0.165 Q^{0.54}$	$Q = 0.08 Q_{crv}$

ATTACHMENT EA (Continued)
CHARLES RIVER TRIBUTARIES

Reach River Miles	From - To	Velocity-Discharge Equation	Average Q in Reach vs. Q at Charles River Village Gage
<u>Bogastow Brook R.M. 48.4</u>			
7.4-6.0	Dopping Brook Confluence to Central Street Bridge Holliston	$v = 0.94 Q^{0.54}$	$Q = 0.04 Q_{crv}$
6.0-0.0	Central Street Bridge, Holliston to Confluence	$v = 0.72 Q^{0.54}$	$Q = 0.07 Q_{crv}$

ATTACHMENT EB

GENERAL POLICY AND
WATER QUALITY CRITERIA
COMMONWEALTH OF MASSACHUSETTS

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MASSACHUSETTS PURE WATER PROGRAM

GENERAL POLICY

General Policy

The following general policies of the Division of Water Pollution Control are as follows:

1. Classification of all waters of the Commonwealth is for the express purpose to establish water quality goals commensurate with the anticipated future uses of the subject water and also that considered attainable by superior technological programs of waste treatment. The classifications designated in the submission to the Secretary are considered to be those that will be attained over the first phase of this program or within a five- to seven-year period depending on the availability of Federal appropriations.
2. All waste sources on fresh waters will be required to be treated to the secondary level regardless of the stream classification assigned. Secondary treatment will generally refer to biological treatment as applicable and/or its industrial wastes treatment equivalent, all as determined by the Division of Water Pollution Control. Secondary treatment efficiencies shall range from 80 to 95 percent BOD removal with correspondingly similar removals on other waste parameters. On coastal and marine waters the degree of treatment required will be that which will attain the particular classification set on the area waters.
3. Tertiary treatment may be required where the estimated increased beneficial water uses can be shown to be economically justifiable. Classifications are not to be considered as immutable. After waste treatment facilities are instituted, continuing programs of surveillance combined with improvements in technology may indicate reclassification to a higher use class should be made.
4. Classification review on D and C streams will be made after completion of the first phase of this program. Classifications shall be made on wet weather considerations in regard to bacteriological control in order to provide the maximum amount of protection insofar as the public is concerned.

5. The Massachusetts compliance program will be tied to a chronological time period associated with those amounts of Federal and State aid that is made available.
6. Section 27 of Chapter 685 describes the responsibilities of the Division in regard to comprehensive planning for water pollution control.
7. It is the policy of the Division whenever low classifications are encountered, the application of which was required by particularly difficult technological problems, that research and development funds be expended to provide for the upgrading of those waters so classified.
8. Where serious water quality control problems are the result of low dependable flows, consideration will be given to the need for and value of storage for waters to be used for low flow augmentation, contingent upon the requirements of Section 39, of Chapter 685 of the Massachusetts Acts of 1966.

PROCEDURE FOR FOLLOW-UP OF IMPLEMENTATION PROGRAM

1. Each polluter listed in the plan of implementation will be informed in writing of the provisions of the Massachusetts Clean Waters Act and the schedule established by the Division for the abatement of pollution. Each will be required to indicate in writing their agreement to proceed with the program in accordance with the schedule.
2. In the event of failure of the polluter to indicate their agreement with the schedule, or failure or to subsequently fail to comply with the schedule, the Division will take appropriate action under the provisions of the Massachusetts Clean Waters Act to effect compliance.
3. If it is shown that any scheduled date or dates cannot be met because of circumstances beyond the control of the polluter, the schedule will be adjusted and the Federal Water Pollution Control Agency so notified.
4. If subsequent investigation or surveys disclose a relevant source of pollution, the source will be added to the plan and the Federal Water Pollution Control Agency so notified.
5. A potential source of pollution (municipality) may be added if preliminary reports show that a sewerage system and treatment facility are needed to prevent the degradation of the waters of the Commonwealth.

COMMONWEALTH OF MASSACHUSETTS
WATER RESOURCES COMMISSION
DIVISION OF WATER POLLUTION CONTROL

WATER QUALITY STANDARDS

Adopted by the Massachusetts Division of Water Pollution Control on March 3, 1967, in accordance with the Provisions of Section 27 (4) of Chapter 21 of the General Laws, and in accordance with the procedure required by Chapter 30A of the General Laws, and after a public hearing held on February 17, 1967

Filed with Secretary
of State on
March 6, 1967

STANDARDS OF WATER QUALITY

1. General

To achieve the objectives of the Massachusetts Clean Water Act and to assure best use of the waters of the Commonwealth, the following standards are adopted and shall be applicable to all waters of the Commonwealth or to different segments of the same waters. The Classes shall be assigned by the Division of Water Pollution Control.

In the classification of waters due consideration will be given to all factors involved including public health, public enjoyment, propagation and protection of fish and wildlife, and economic and social development. Classifications are not intended to permit indiscriminate waste disposal or to allow minimum efforts of waste treatment under any circumstances.

When an effluent is permitted to be discharged to the receiving waters, cognizance shall be given both in time and distance to allow for mixing of effluent and stream. Such distances required for complete mixing shall not affect the water usage Class adopted.

Recommendations on other waste parameters will constitute a portion of the continuing effort of the Division as improved standard methods are developed or revisions consistent with the enhancement of the waters of the Commonwealth are justified.

Water quality parameters not specifically denoted shall not exceed the recommended limits on the most sensitive and governing water class use. In areas where fisheries are the governing consideration and approved limits have not been established, bioassays shall be performed as required by the appropriate agencies.

Standards of Water Quality

Fresh Waters

Class A - Waters designated for use as public water supplies in accordance with Chapter 111 of the General Laws. Character uniformly excellent.

Standards of Quality

<u>Item</u>	<u>Water Quality Criteria</u>
1. Dissolved oxygen	Not less than 75 percent of saturation during at least 16 hours of any 24-hour period and not less than 5 mg/l at any time.
2. Sludge deposits-solid refuse-floating solids-oil-grease-scum	None allowable
3. Color and turbidity	None other than of natural origin
4. Coliform bacteria per 100 ml.	Not to exceed an average value of 50 during any monthly sampling period
5. Taste and odor	None other than of natural origin
6. pH	As naturally occurs
7. Allowable temperature increase	None other than of natural origin
8. Chemical constituents	None in concentrations or combinations which would be harmful or offensive to humans, or harmful to animal or aquatic life.
9. Radioactivity	None other than that occurring from natural phenomena

Class B - Suitable for bathing and recreational purposes, including water contact sports. Acceptable for public water supply with appropriate treatment. Suitable for agricultural, and certain industrial cooling and process uses; excellent fish and wildlife habitat; excellent aesthetic value.

Standards of Quality

<u>Item</u>	<u>Water Quality Criteria</u>
1. Dissolved oxygen	Not less than 75 percent of saturation during at least 16 hours of any 24-hour period and not less than 5 mg/l at any time.
2. Sludge deposits-solid refuse-floating solids-oils-grease-scum	None allowable
3. Color and turbidity	None in such concentrations that would impair any usages specifically assigned to this class.
4. Coliform bacteria per 100 ml.	Not to exceed an average value of 1000 during any monthly sampling period nor 2400 in more than 20 percent of samples examined during such period.
5. Taste and odor	None in such concentrations that would impair any usages specifically assigned to this class and none that would cause taste and odor in edible fish.
6. pH	6.5 - 8.0
7. Allowable temperature increase	None except where the increase will not exceed the recommended limit on the most sensitive receiving water use and in no case exceed 83°F in warm water fisheries, and 68°F in cold water fisheries, or in any case raise the normal temperature of the receiving water more than 4°F.
8. Chemical constituents	None in concentrations or combinations which would be harmful or offensive to human, or harmful to animal or aquatic life or any water use specifically assigned to this class.

9. Radioactivity
- None in concentrations or combinations which would be harmful to human, animal or aquatic life for the appropriate water use. None in such concentrations which would result in radio-nuclide concentrations in aquatic life which exceed the recommended limits for consumption by humans.
10. Total phosphate
- Not to exceed an average of 0.05 mg/l as P during any monthly sampling period.
11. Ammonia
- Not to exceed an average of 0.5 mg/l as N during any monthly sampling period.
12. Phenols
- Shall not exceed .001 mg/l at any time.

Class C - Suitable for recreational boating; habitat for wildlife and common food and game fishes indigenous to the region; certain industrial cooling and process uses; under some conditions acceptable for public water supply with appropriate treatment. Suitable for irrigation of crops used for consumption after cooking. Good aesthetic value.

Standards of Quality

<u>Item</u>	<u>Water Quality Criteria</u>
1. Dissolved oxygen	Not less than 5 mg/l during at least 16 hours of any 24-hour period nor less than 3 mg/l at any time. For seasonal cold water fisheries at least 5 mg/l must be maintained.
2. Sludge deposits-solid refuse-floating solids-oils-grease-scum	None allowable except those amounts that may result from the discharge from waste treatment facilities providing appropriate treatment.
3. Color and turbidity	None allowable in such concentrations that would impair any usages specifically assigned to this class.
4. Coliform bacteria	None in such concentrations that would impair any usages specifically assigned to this class.
5. Taste and odor	None in such concentrations that would impair any usages specifically assigned to this class, and none that would cause taste and odor to edible fish.
6. pH	6.0 - 8.5
7. Allowable temperature increase	None except where the increase will not exceed the recommended limits on the most sensitive receiving water use and in no case exceed 83°F in warm water fisheries, and 68°F in cold water fisheries, or in any case raise the normal temperature of the receiving water more than 4°F.
8. Chemical constituents	None in concentrations or combinations which would be harmful or offensive to human, or harmful to animal or aquatic life or any water use specifically assigned to this class.

9. Radioactivity
- None in concentrations or combinations which would be harmful to human, animal or aquatic life for the appropriate water use. None in such concentrations which would result in radio-nuclide concentrations in aquatic life which exceed the recommended limits for consumption by humans.
10. Total phosphate
- Not to exceed an average of 0.05 mg/l as P during any monthly sampling period.
11. Ammonia
- Not to exceed an average of 1.0 mg/l as N during any monthly sampling period.
12. Phenols
- Not to exceed an average of 0.002 mg/l at any time.

Class D - Suitable for aesthetic enjoyment, power, navigation and certain industrial cooling and process uses. Class D waters will be assigned only where a higher water use class cannot be attained after all appropriate waste treatment methods are utilized.

Standards of Quality

<u>Item</u>	<u>Specifications</u>
1. Dissolved oxygen	Not less than 2 mg/l at any time.
2. Sludge deposits-solid refuse-floating solids-oils-grease-scum	None allowable except those amounts that may result from the discharge from waste treatment facilities providing appropriate treatment.
3. Color and turbidity	None in such concentrations that would impair any usages specifically assigned to this class.
4. Coliform bacteria	None in such concentrations that would impair any usages specifically assigned to this class.
5. Taste and odor	None in such concentrations that would impair any usages specifically assigned to this class.
6. pH	6.0 - 9.0
7. Allowable temperature increase	None except where the increase will not exceed the recommended limits on the most sensitive receiving water use and in no case exceed 90°F.
8. Chemical constituents	None in concentrations or combinations which would be harmful to human, animal or aquatic life for the designated water use.
9. Radioactivity	None in such concentrations or combinations which would be harmful to human, animal or aquatic life for the designated water use. None in such concentrations which will result in radio-nuclide concentrations in aquatic life which exceed the recommended limits for consumption by humans.

Notes:

1. All wastes shall receive appropriate waste treatment which is defined as secondary treatment with disinfection or its industrial waste treatment equivalent except when a higher degree of treatment is required to meet the objectives of the water quality standards, all as determined by the Division of Water Pollution Control. Disinfection from October 1 to May 1 may be discontinued at the discretion of the Division of Water Pollution Control.
2. Appropriate water supply treatment is as determined by the Massachusetts Department of Public Health.
3. These water quality standards do not apply to conditions brought about by natural causes.
4. Class B and C waters shall be substantially free of pollutants that will:
 - (1) unduly affect the composition of bottom fauna
 - (2) unduly affect the physical or chemical nature of the bottom
 - (3) interfere with the spawning of fish or their eggs
5. The average minimum consecutive seven-day flow to be expected once in ten years shall be used in the interpretation of the standards, except where noted.
6. The amount of disinfection required shall be equivalent to a free and combined chlorine residual of at least 1.0 mg/l after 15 minutes contact time during peak hourly flow or maximum rate of pumpage.

ATTACHMENT EC

LOCATION OF WATER QUALITY SAMPLING STATIONS

1967 AND 1969 SURVEYS

CHARLES RIVER WATERSHED STUDY

Location of EPA Sampling Stations - 1967 Survey

<u>Station Number</u>	<u>Location</u>	<u>River Mile</u>
C-1	Main Street Bridge, Milford	75.2
C-2	Mellon Street Bridge, Milford	73.1
C-3	Mine Brook along Pond Street, Franklin	63.2-0.7
C-4	Bent Street Bridge, Medway	60.2
C-5	Stop River at Causeway Street Bridge, Medfield	51.8-0.2
C-6	Main Street Bridge, Medfield	51.2
C-7	Hospital Road Bridge, Medfield	47.3
C-8	Union Street Bridge, South Natick	41.1
C-9	0.2 mi. above Charles River Village Gage, Dover	34.5
C-10	Ames Street Bridge, Dedham	26.8
C-11	Bridge Street Bridge, Dedham - below Mother Brook	25.3
C-12	Wellesley Gaging Station	20.0
C-13	Commonwealth Avenue Bridge, Newton	15.4
C-14	Moody Street Bridge, Waltham	12.6
C-15	Foot Bridge above Watertown Dam, Watertown	9.8
C-16	Weeks Foot Bridge, Cambridge	5.1
C-17	Longfellow Bridge, Boston	1.7

CHARLES RIVER WATERSHED STUDY

Location of State Sampling Stations - 1967 Survey

<u>Station Number</u>	<u>Location</u>	<u>River Mile</u>
S-1	Charles River below Echo Lake, Cedar Street Bridge, Milford	78.2
S-2	Charles River, Dilla Street Bridge, Milford	76.5
S-3	Charles River along East Shore of Cedar Swamp Pond, Milford	76.1
S-4	Charles River, Depot Street Bridge, Bellingham	70.1
S-5	Mine Brook, Grove Street Bridge, Franklin	63.2-4.1
S-6	Chicken Brook, Main Street Bridge, Medway	63.0-0.6
S-7	Eagle Brook (Mill River), Outlet of Lake Pearl, Franklin Street Bridge, Wrentham	57.6-5.5
S-8	Mill River, Main Street Bridge, Norfolk	57.6-1.9
S-9	Stop River, South Street Bridge, Medfield	51.8-1.7
S-10	Bogastow Brook, Outlet of Bogastow Pond, Orchard Street Bridge, Millis	48.4-2.3
S-11	Charles River, Hospital Road Bridge, Medfield	47.3
S-12	Waban Brook, Outlet of Lake Waban, Washington Street Bridge, Wellesley	39.4-0.7
S-13	Rosemary Brook, Oakland Street Bridge, Wellesley	18.9-1.2
S-14	Charles River at Culvert near Newton Incinerator	Along East Bank
S-15	Charles River at Culvert - Just Downstream of Station S-14	Near R.M. 14.3
S-16	Charles River at Woerd Avenue Bridge, Waltham	" "
S-17	Charles River at Watertown Dam	9.8

CHARLES RIVER WATERSHED STUDY

Location of EPA Sampling Stations - 1969 Survey

<u>Station Number</u>	<u>Location</u>	<u>River Mile</u>
F-1	Mellon Street Bridge, Milford (Same as Station C-2, 1967 Survey)	73.1
F-2	Hospital Road Bridge, Medfield (Same as Station C-7, 1967 Survey)	47.3
F-3	Commonwealth Avenue Bridge, Newton (Same as Station C-13, 1967 Survey)	15.4
F-4	Moody Street Bridge, Waltham (Same as Station C-14, 1967 Survey)	12.6
F-5	North Beacon Street Bridge, Boston	8.1
F-6	Longfellow Bridge, Boston (Same as Station C-17, 1967 Survey)	1.7

ATTACHMENT ED

COST BREAKDOWN OF ALTERNATE
TREATMENT PLANT CONFIGURATIONS

The following Tables show a more detailed cost breakdown of various possible treatment plant configurations than has been presented in the text. Average annual capital costs of treatment plants and interceptors have been divided into those portions eligible under existing regulations for Federal grants (55 percent), State grants (25 percent) and to be financed by the community (20 percent). Presently, the complete cost of operation and maintenance is borne by the community. For regional plants and major interceptors that transport the wastes of more than one community, costs have been apportioned on the basis of the design flow from each town. This method of cost allocation is commonly used, however, in some cases it can result in inequities. Therefore, other methods of cost apportionment should be investigated before a final decision is made.

TABLE ED-1

1970-1995

Individual Treatment Plants--Milford, Bellingham, Franklin, Medway and Wrentham

	Average Annual Capital Cost	Federal Grant 55%	State Grant 25%	Cost to Community 20%	Annual O&M	Total Annual Cost to Community	Total Annual Cost
Milford	\$202,000	\$111,000	\$50,000	\$41,000	\$124,000	\$165,000	\$326,000
Bellingham	68,000	38,000	17,000	14,000	32,000	46,000	100,000
Franklin	226,000	124,000	56,000	46,000	130,000	176,000	356,000
Medway	71,000	39,000	18,000	14,000	36,000	50,000	107,000
Wrentham	97,000	53,000	24,000	20,000	51,000	71,000	148,000

TABLE ED-2

1970-1995

Regional Treatment Plant--Milford, Bellingham, Franklin, Medway and Wrentham

	Average Annual Capital Cost	Federal Grant 55%	State Grant 25%	Cost to Community 20%	Annual O&M	Total Annual Cost to Community	Total Annual Cost
Milford							
Treatment	\$149,000	\$ 82,000	\$37,000	\$30,000	\$94,000	\$124,000	\$243,000
Interception	207,000	114,000	52,000	41,000	0	41,000	207,000
Subtotal	356,000	196,000	89,000	71,000	94,000	165,000	450,000
Bellingham							
Treatment	30,000	16,000	8,000	6,000	19,000	25,000	49,000
Interception	28,000	15,000	7,000	6,000	0	6,000	28,000
Subtotal	58,000	31,000	15,000	12,000	19,000	31,000	77,000
Franklin							
Treatment	176,000	97,000	44,000	35,000	111,000	146,000	287,000
Interception	131,000	72,000	33,000	26,000	0	26,000	131,000
Subtotal	307,000	169,000	77,000	61,000	111,000	172,000	418,000

TABLE ED-2 (Continued)

	Average Annual Capital Cost	Federal Grant 55%	State Grant 25%	Cost to Community 20%	Annual O&M	Total Annual Cost to Community	Total Annual Cost
Medway							
Treatment	\$ 32,000	\$18,000	\$ 8,000	\$ 6,000	\$21,000	\$ 27,000	\$ 53,000
Interception	3,000	1,600	800	600	0	600	3,000
Subtotal	35,000	19,600	8,800	6,600	21,000	27,600	56,000
Wrentham							
Treatment	51,000	28,000	13,000	10,000	32,000	42,000	83,000
Interception	46,000	25,000	12,000	9,000	0	9,000	46,000
Subtotal	97,000	53,000	25,000	19,000	32,000	51,000	129,000
Total	\$853,000	\$468,000	\$215,000	\$170,000	\$277,000	\$447,000	\$1,130,000
Total from Table ED-1	\$664,000	\$365,000	\$165,000	\$135,000	\$373,000	\$508,000	\$1,037,000

TABLE ED-3

1970-1995

Regional Treatment Plant--Bellingham, Franklin, Medway and Wrentham

	Average Annual Capital Cost	Federal Grant 55%	State Grant 25%	Cost to Community 20%	Annual O&M	Total Annual Cost Community	Total Annual Cost
Bellingham							
Treatment	\$ 33,000	\$18,000	\$ 8,000	\$ 7,000	\$22,000	\$29,000	\$55,000
Interception	63,000	35,000	16,000	12,000	0	12,000	63,000
Subtotal	96,000	53,000	24,000	19,000	22,000	41,000	118,000
Franklin							
Treatment	195,000	107,000	49,000	39,000	128,000	167,000	323,000
Interception	149,000	82,000	38,000	29,000	0	29,000	149,000
Subtotal	344,000	189,000	87,000	68,000	128,000	196,000	472,000
Medway							
Treatment	36,000	20,000	9,000	7,000	24,000	31,000	60,000
Interception	3,000	1,600	800	600	0	600	3,000
Subtotal	39,000	21,600	9,800	7,600	24,000	31,600	63,000

TABLE ED-3 (Continued)

	Average Annual Capital Cost	Federal Grant 55%	State Grant 25%	Cost to Community 20%	Annual O&M	Total Annual Cost to Community	Total Annual Cost
Wrentham							
Treatment	\$ 56,000	\$31,000	\$14,000	\$ 11,000	\$ 37,000	\$ 48,000	\$ 93,000
Interception	47,000	26,000	12,000	9,000	0	9,000	47,000
Subtotal	103,000	57,000	26,000	20,000	37,000	57,000	140,000
Total	\$582,000	\$321,000	\$147,000	\$115,000	\$211,000	\$326,000	\$793,000
Total of Bellingham, Franklin, Medway and Wrentham from ED-1	\$462,000	\$254,000	\$110,000	\$ 94,000	\$249,000	\$343,000	\$711,000

TABLE ED-4

Dual Community Plant--Milford and Bellingham

	Average Annual Capital Cost	Federal Grant 55%	State Grant 25%	Cost to Community 20%	Annual O&M	Total Annual Cost to Community	Total Annual Cost
Milford							
Treatment	\$194,000	\$107,000	\$48,000	\$39,000	\$102,000	\$141,000	\$296,000
Interception	70,000	38,000	18,000	14,000	0	14,000	70,000
Subtotal	264,000	145,000	66,000	53,000	102,000	155,000	366,000
Bellingham							
Treatment	39,000	21,000	10,000	8,000	21,000	29,000	60,000
Interception	0	0	0	0	0	0	0
Total	\$303,000	\$166,000	\$76,000	\$61,000	\$123,000	\$184,000	\$426,000
Total of Milford and Bellingham from ED-1	\$270,000	\$149,000	\$67,000	\$55,000	\$156,000	\$211,000	\$426,000

TABLE ED-5

1970-1995

Dual Community Plant--Medway and Wrentham

	Average Annual Capital Cost	Federal Grant 55%	State Grant 25%	Cost to Community 20%	Annual O&M	Total Annual Cost to Community	Total Annual Cost
Medway							
Treatment	\$53,000	\$24,000	\$13,000	\$11,000	\$30,000	\$41,000	\$83,000
Interception	11,000	6,000	3,000	2,000	0	2,000	11,000
Subtotal	64,000	35,000	16,000	13,000	30,000	43,000	94,000
Wrentham							
Treatment	83,000	45,000	21,000	17,000	48,000	65,000	131,000
Interception	46,000	25,000	12,000	9,000	0	9,000	46,000
Subtotal	129,000	70,000	33,000	26,000	48,000	74,000	177,000
Total	\$193,000	\$105,000	\$49,000	\$39,000	\$78,000	\$117,000	\$271,000
Total of Medway and Wrentham from ED-1	\$168,000	\$ 92,000	\$42,000	\$34,000	\$87,000	\$121,000	\$255,000

TABLE ED-6

1995-2020

Individual Treatment Plants - Milford, Bellingham, Franklin, Medway and Wrentham

	Average Annual Capital Cost	Federal Grant 55%	State Grant 25%	Cost to Community 20%	Annual O&M	Total Annual Cost to Community	Total Annual Cost
Milford	\$341,000	\$188,000	\$85,000	\$68,000	\$220,000	\$288,000	\$561,000
Bellingham	142,000	79,000	35,000	28,000	77,000	105,000	219,000
Franklin	432,000	238,000	108,000	86,000	269,000	355,000	701,000
Medway	121,000	67,000	30,000	24,000	74,000	98,000	195,000
Wrentham	214,000	118,000	53,000	43,000	120,000	163,000	334,000
Total	\$1,250,000	\$690,000	\$311,000	\$249,000	\$760,000	\$1,009,000	\$2,010,000

TABLE ED-7

1995-2020

Regional Treatment Plant--Milford, Bellingham, Franklin, Medway and Wrentham
(Individual Plants over Previous Phase)

	Average Annual Capital Cost	Federal Grant 55%	State Grant 25%	Cost to Community 20%	Annual O&M	Total Annual Cost to Community	Total Annual Cost
Milford							
Treatment	\$238,000	\$130,000	\$60,000	\$48,000	\$161,000	\$209,000	\$399,000
Interception	276,000	152,000	69,000	55,000	0	55,000	276,000
Subtotal	514,000	282,000	129,000	103,000	161,000	264,000	675,000
Bellingham							
Treatment	68,000	37,000	17,000	14,000	46,000	60,000	114,000
Interception	68,000	37,000	17,000	14,000	0	14,000	68,000
Subtotal	136,000	74,000	34,000	28,000	46,000	74,000	182,000
Franklin							
Treatment	341,000	188,000	85,000	68,000	229,000	297,000	570,000
Interception	211,000	116,000	53,000	42,000	0	42,000	211,000
Subtotal	552,000	304,000	138,000	110,000	229,000	339,000	781,000

TABLE ED-7 (Continued)

	Average Annual Capital Cost	Federal Grant 55%	State Grant 25%	Cost to Community 20%	Annual O&M	Total Annual Cost to Community	Total Annual Cost
Medway							
Treatment	\$60,000	\$33,000	\$15,000	\$12,000	\$40,000	\$52,000	\$100,000
Interception	9,000	5,000	2,000	2,000	0	2,000	9,000
Subtotal	69,000	38,000	17,000	14,000	40,000	54,000	109,000
Wrentham							
Treatment	127,000	70,000	32,000	25,000	84,000	109,000	211,000
Interception	74,000	41,000	18,000	15,000	0	15,000	74,000
Subtotal	201,000	111,000	50,000	40,000	84,000	124,000	285,000
Total	\$1,472,000	\$809,000	\$368,000	\$295,000	\$560,000	\$855,000	\$2,032,000
Total from ED-6	\$1,250,000	\$690,000	\$311,000	\$249,000	\$760,000	\$1,009,000	\$2,010,000

TABLE ED-8

1995-2020

Regional Treatment Plant--Bellingham, Franklin, Medway and Wrentham
(Individual Plants over Previous Phase)

	Average Annual Capital Cost	Federal Grant 55%	State Grant 25%	Cost to Community 20%	Annual O&M	Total Annual Cost to Community	Total Annual Cost
Bellingham							
Treatment	\$ 74,000	\$41,000	\$18,000	\$15,000	\$46,000	\$61,000	\$120,000
Interception	102,000	57,000	25,000	20,000	0	20,000	102,000
Subtotal	176,000	98,000	43,000	35,000	46,000	81,000	222,000
Franklin							
Treatment	368,000	202,000	92,000	74,000	232,000	306,000	600,000
Interception	235,000	129,000	59,000	47,000	0	47,000	235,000
Subtotal	603,000	331,000	151,000	121,000	232,000	353,000	835,000
Medway							
Treatment	65,000	36,000	16,000	13,000	40,000	53,000	105,000
Interception	6,000	3,000	2,000	1,000	0	1,000	6,000
Subtotal	71,000	39,000	18,000	14,000	40,000	54,000	111,000

TABLE ED-8 (Continued)

	Average Annual Capital Cost	Federal Grant 55%	State Grant 25%	Cost to Community 20%	Annual O&M	Total Annual Cost to Community	Total Annual Cost
Wrentham							
Treatment	\$136,000	\$75,000	\$34,000	\$27,000	\$84,000	\$111,000	\$220,000
Interception	74,000	41,000	18,000	15,000	0	15,000	74,000
Subtotal	<u>210,000</u>	<u>116,000</u>	<u>52,000</u>	<u>42,000</u>	<u>84,000</u>	<u>126,000</u>	<u>294,000</u>
Total	\$1,060,000	\$584,000	\$264,000	\$212,000	\$402,000	\$614,000	\$1,462,000
Total of Bellingham, Franklin, Medway and Wrentham from ED-6	\$910,000	\$502,000	\$227,000	\$181,000	\$540,000	\$721,000	\$1,450,000

TABLE ED-9

1970-1995

Individual Treatment Plants--Norfolk, Millis, Medfield and Holliston

	Average Annual Capital Cost	Federal Grant 55%	State Grant 25%	Cost to Community 20%	Annual O&M	Total Annual Cost to Community	Total Annual Cost
Norfolk	\$68,000	\$37,000	\$17,000	\$14,000	\$40,000	\$54,000	\$108,000
Millis	93,000	51,000	23,000	19,000	60,000	79,000	153,000
Medfield	113,000	62,000	28,000	23,000	62,000	85,000	175,000
Holliston	<u>84,000</u>	<u>46,000</u>	<u>21,000</u>	<u>17,000</u>	<u>41,000</u>	<u>58,000</u>	<u>125,000</u>
Total	\$358,000	\$196,000	\$89,000	\$73,000	\$203,000	\$276,000	\$561,000

TABLE ED-10

1970-1995

Dual Community Plant--Millis and Medfield

	Average Annual Capital Cost	Federal Grant 55%	State Grant 25%	Cost to Community 20%	Annual O&M	Total Annual Cost to Community	Total Annual Cost
Millis							
Treatment	\$74,000	\$43,000	\$18,000	\$13,000	\$50,000	\$63,000	\$124,000
Interception	19,000	10,000	5,000	4,000	0	4,000	19,000
Subtotal	93,000	53,000	23,000	17,000	50,000	67,000	143,000
Medfield							
Treatment	92,000	51,000	23,000	18,000	62,000	80,000	154,000
Interception	14,000	7,000	4,000	3,000	0	3,000	14,000
Subtotal	106,000	58,000	27,000	21,000	62,000	83,000	168,000
Total	\$199,000	\$111,000	\$50,000	\$38,000	\$112,000	\$150,000	\$311,000
Total of Millis and Medfield from ED-9	\$206,000	\$113,000	\$51,000	\$42,000	\$122,000	\$164,000	\$328,000

TABLE ED-11

1970-1995

Tri-Community Plant--Millis, Medfield and Holliston

	Average Annual Capital Cost	Federal Grant 55%	State Grant 25%	Cost to Community 20%	Annual Cost	Total Annual Cost to Community	Total Annual Cost
Millis							
Treatment	\$74,000	\$41,000	\$18,000	\$15,000	\$43,000	\$58,000	\$117,000
Interception	15,000	8,000	4,000	3,000	0	3,000	15,000
Subtotal	89,000	49,000	22,000	18,000	43,000	61,000	132,000
Medfield							
Treatment	93,000	51,000	23,000	19,000	53,000	72,000	146,000
Interception	14,000	7,000	4,000	3,000	0	3,000	14,000
Subtotal	107,000	58,000	27,000	22,000	53,000	75,000	160,000
Holliston							
Treatment	56,000	31,000	14,000	11,000	32,000	43,000	88,000
Interception	69,000	38,000	17,000	14,000	0	14,000	69,000
Subtotal	125,000	69,000	31,000	25,000	32,000	57,000	157,000
Total	\$321,000	\$176,000	\$80,000	\$65,000	\$128,000	\$193,000	\$449,000
Total of Millis, Medfield and Holliston from ED-9							
	\$290,000	\$159,000	\$72,000	\$59,000	\$163,000	\$222,000	\$453,000

TABLE ED-12

1995-2020

Individual Treatment Plants--Norfolk, Millis, Medfield and Holliston

	Average Annual Capital Cost	Federal Grant 55%	State Grant 25%	Cost to Community 20%	Annual Cost	Total Annual Cost to Community	Total Annual Cost
Norfolk	\$128,000	\$70,000	\$32,000	\$26,000	\$69,000	\$95,000	\$197,000
Millis	179,000	98,000	45,000	36,000	108,000	144,000	287,000
Medfield	251,000	138,000	63,000	50,000	143,000	193,000	394,000
Holliston	148,000	81,000	37,000	30,000	102,000	132,000	250,000
Total	\$706,000	\$387,000	\$177,000	\$142,000	\$422,000	\$564,000	\$1,128,000

TABLE ED-13

1995-2020

Regional Treatment Plant--Norfolk, Millis, Medfield and Holliston
(Individual Plant over Previous Phase)

	Average Annual Capital Cost	Federal Grant 55%	State Grant 25%	Cost to Community 20%	Annual O&M	Total Annual Cost to Community	Total Annual Cost
Norfolk							
Treatment	\$73,000	\$40,000	\$18,000	\$15,000	\$46,000	\$61,000	\$119,000
Interception	59,000	32,000	15,000	12,000	0	12,000	59,000
Subtotal	132,000	72,000	33,000	27,000	46,000	73,000	178,000
Millis							
Treatment	124,000	68,000	31,000	25,000	78,000	103,000	202,000
Interception	20,000	11,000	5,000	4,000	0	4,000	20,000
Subtotal	144,000	79,000	36,000	29,000	78,000	107,000	222,000
Medfield							
Treatment	196,000	108,000	49,000	39,000	123,000	162,000	319,000
Interception	22,000	12,000	6,000	4,000	0	4,000	22,000
Subtotal	218,000	120,000	55,000	43,000	123,000	166,000	341,000

TABLE ED-13 (Continued)

	Average Annual Capital Cost	Federal Grant 55%	State Grant 25%	Cost to Community 20%	Annual O&M	Total Annual Cost to Community	Total Annual Cost
Holliston							
Treatment	\$91,000	\$50,000	\$23,000	\$18,000	\$57,000	\$75,000	\$148,000
Interception	89,000	49,000	22,000	18,000	0	18,000	89,000
Subtotal	<u>180,000</u>	<u>99,000</u>	<u>45,000</u>	<u>36,000</u>	<u>57,000</u>	<u>93,000</u>	<u>237,000</u>
Total	\$674,000	\$370,000	\$169,000	\$135,000	\$304,000	\$439,000	\$978,000
Total from ED-12	\$706,000	\$387,000	\$177,000	\$142,000	\$422,000	\$564,000	\$1,128,000

ATTACHMENT EE

DEVELOPMENT AND METHOD OF APPLICATION
OF CURVES OF AVERAGE ANNUAL REDUCTION
IN TREATMENT COSTS VERSUS FLOW AUGMENTATION
AMOUNTS AND FLOW REGIMES

1. Development of Curves

The river has been divided into six zones under an individual treatment plant scheme and two zones under a regional treatment plant scheme. The location of each zone is given in Table EE-1, and shown on Figures EE-1 and EE-2. For each zone, flow versus waste load discharged to the zone has been analyzed. The determined flow augmentation amounts are exclusive of waste flows discharged to the stream and of base flows in the stream. Typical plots are shown on Figure EE-3, which represents Zone 4 under individual waste treatment plant conditions.

Aeration was provided to assure that the dissolved oxygen concentration in the waste effluent would be 6 mg/l. This was found to provide the most economical combination of treatment and effluent aeration at all flow levels to assure the desired dissolved oxygen concentrations in the stream.

Using the generalized cost curves developed by Robert Smith of the Advanced Waste Treatment Branch, Division of Research, EPA, average annual costs of treatment required to limit waste loads discharged to the stream to a specified amount were computed for each zone. The costs presented graphically are over and above the cost of plants providing the minimum treatment level that is expected to be required of all wastes in the year 1980. For purposes of this study, the minimum treatment level includes secondary treatment and six months' operation of a coagulation and sedimentation process. It is expected that nutrient removal will be necessary in the Charles River Watershed because of the high ratio of waste flows to natural stream flow.

Costs were computed for the periods 1970 to 1995, and 1995 to 2020, and were adjusted to equivalent annual costs over the fifty-year period, 1970-2020, in order to be directly comparable to reservoir costs. The costs were based on an interest rate of 4-5/8 percent. The costs reflect both capital costs and operation and maintenance expenses.

Operation of those treatment processes above the minimum required treatment was assumed necessary for six months per year. The curves developed for Zone 4 are shown on Figure EE-4. They show the adjusted costs of treatment versus waste load for the periods 1970 to 1995, 1995 to 2020, and a composite curve covering the entire 50-year period.

By combining Figures EE-3 and EE-4, a curve of average annual cost of treatment over a 50-year period versus flow augmentation for the months of July and August (30°C river temperature) was drawn (Figure EE-5). During cooler months, less flow is required to maintain a given stream dissolved oxygen concentration for the

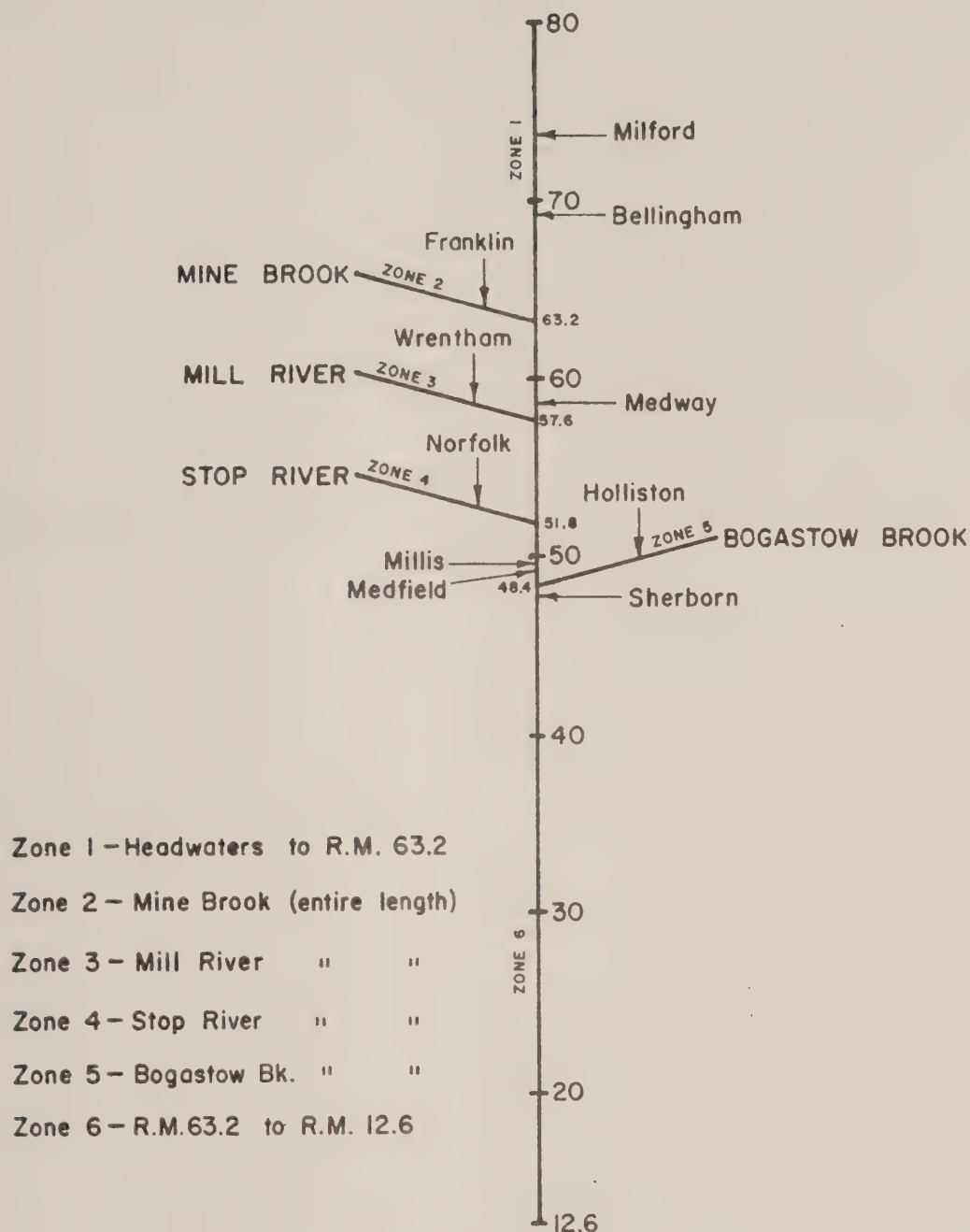
same level of waste treatment. The ratios of flows required at 20°C (May and October) and 25°C (June and September) to those required at 30°C for the same waste load have been calculated to establish a flow regime. Flow regimes, once established, may then be used to determine and compare the costs of reservoir storage with corresponding treatment cost reductions for purposes of project formulation.

For Zone 4, the augmentation regime is as follows: Where the augmentation required during July and August (30°C) is Q_{I4} , the augmentation required during June and September (25°C) is $0.53 Q_{I4}$ and the augmentation required during May and October (20°C) is $0.33 Q_{I4}$.

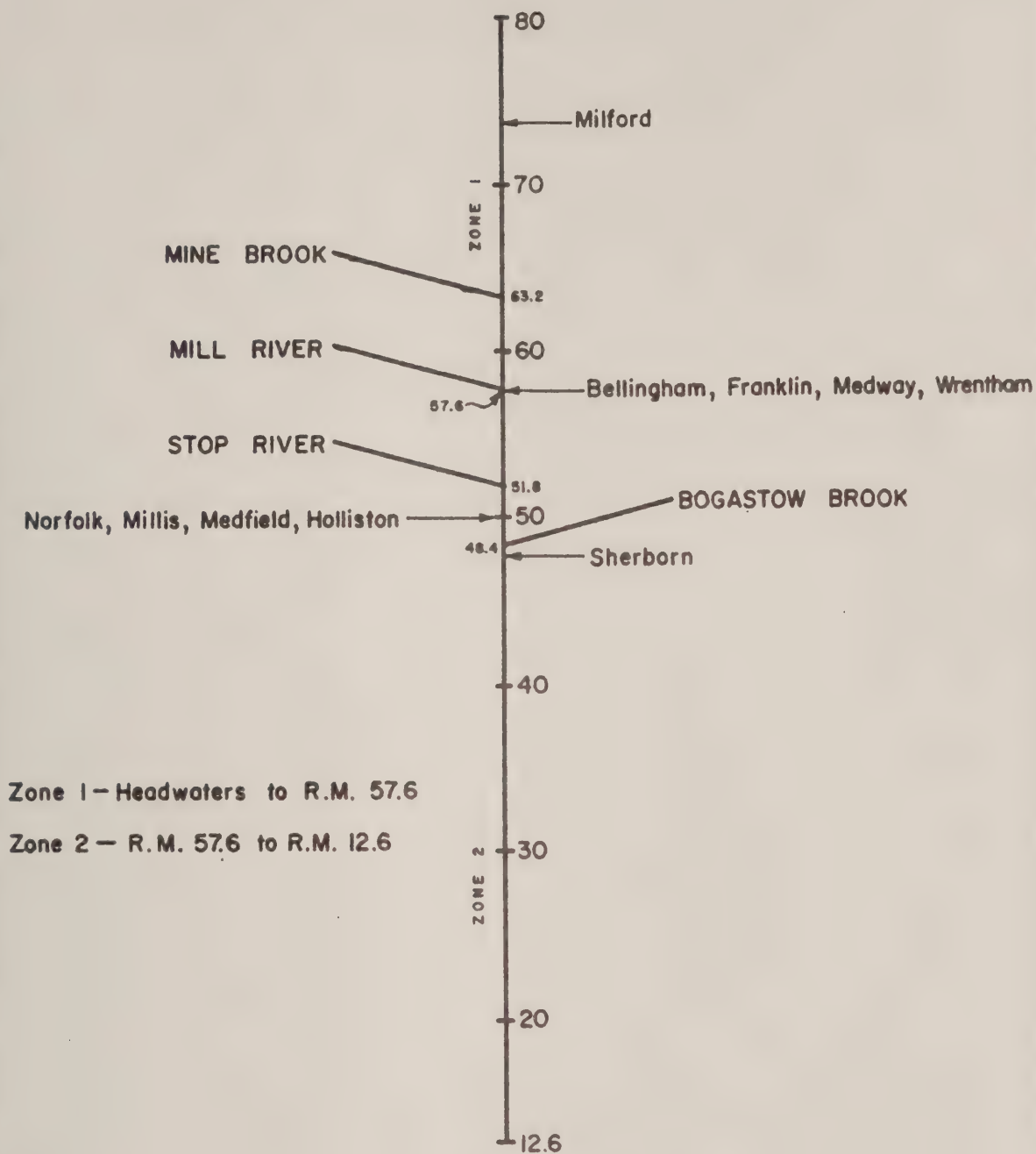
For those periods when natural flows coupled with minimum treatment are adequate to maintain dissolved oxygen levels in the Charles River, operation of advanced waste treatment processes is unnecessary. Based on the historical record of mean monthly flows recorded at the Charles River Village gage, the average annual costs of treatment for each zone have been reduced to account for the decreased operation and maintenance costs during periods of high stream flow (dotted line on Figure EE-5).

With no flow augmentation the average annual cost of treatment is \$47,000. At an assumed flow of 10 cfs plus the base flow and waste flow in the zone, there is no additional cost of treatment above the minimum required treatment. Thus, a 10 cfs augmentation flow would result in an average annual decrease in treatment cost of \$47,000. Figure E-6, which is the reverse of Figure E-5, shows a plot of average annual reductions in treatment cost versus flow augmentation for the months of July and August (30°C river temperature).

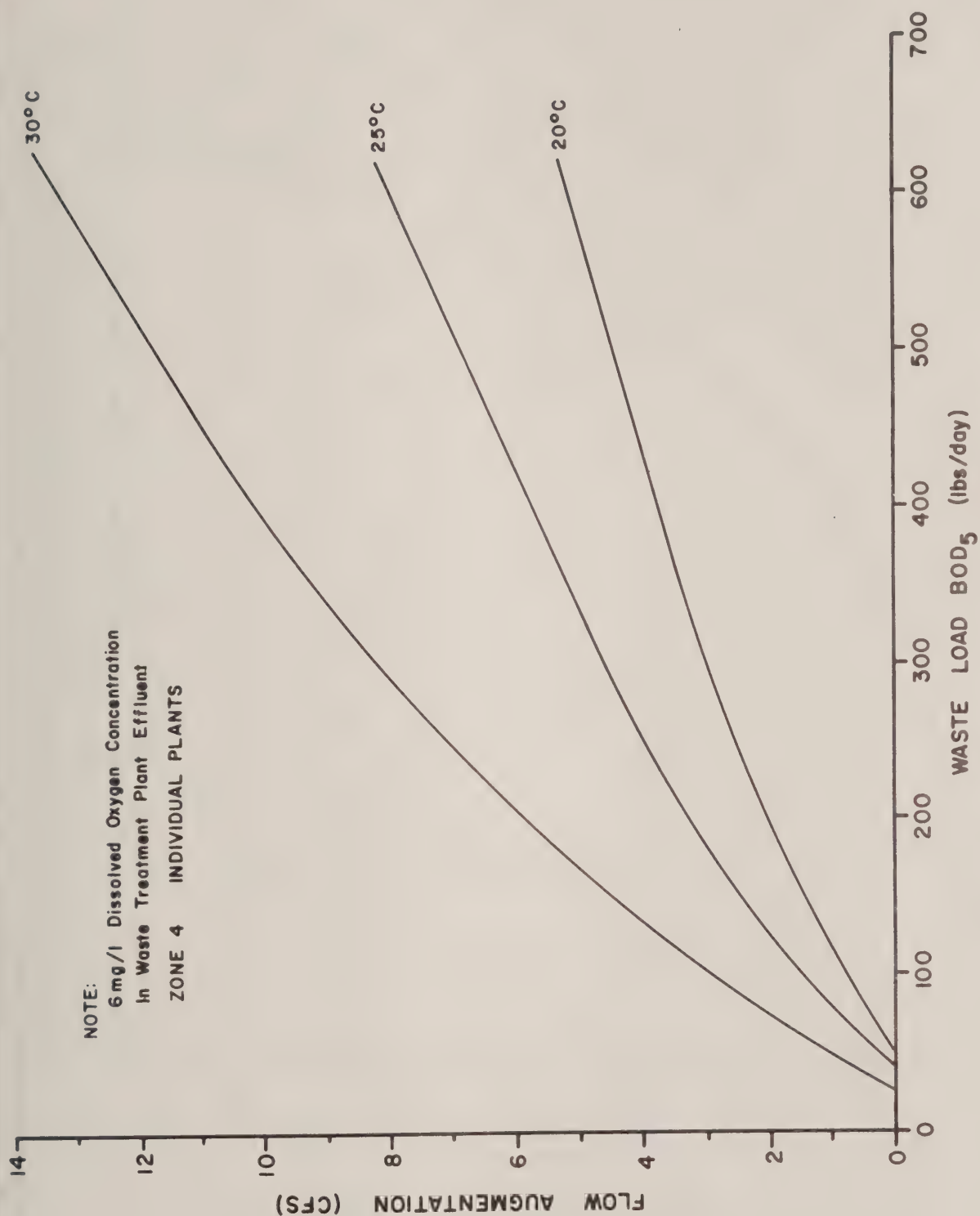
On the following pages are curves of average annual reductions in treatment costs over 50 years versus flow augmentation amounts for each zone for both individual and regional plants (Figures EE-7 through EE-14) and the flow regime for each zone (Tables EE-2 and EE-3).



LOCATION OF ZONES
FOR
INDIVIDUAL TREATMENT PLANTS



LOCATION OF ZONES
FOR
REGIONAL TREATMENT PLANTS



FLOW AUGMENTATION VS. WASTE LOAD

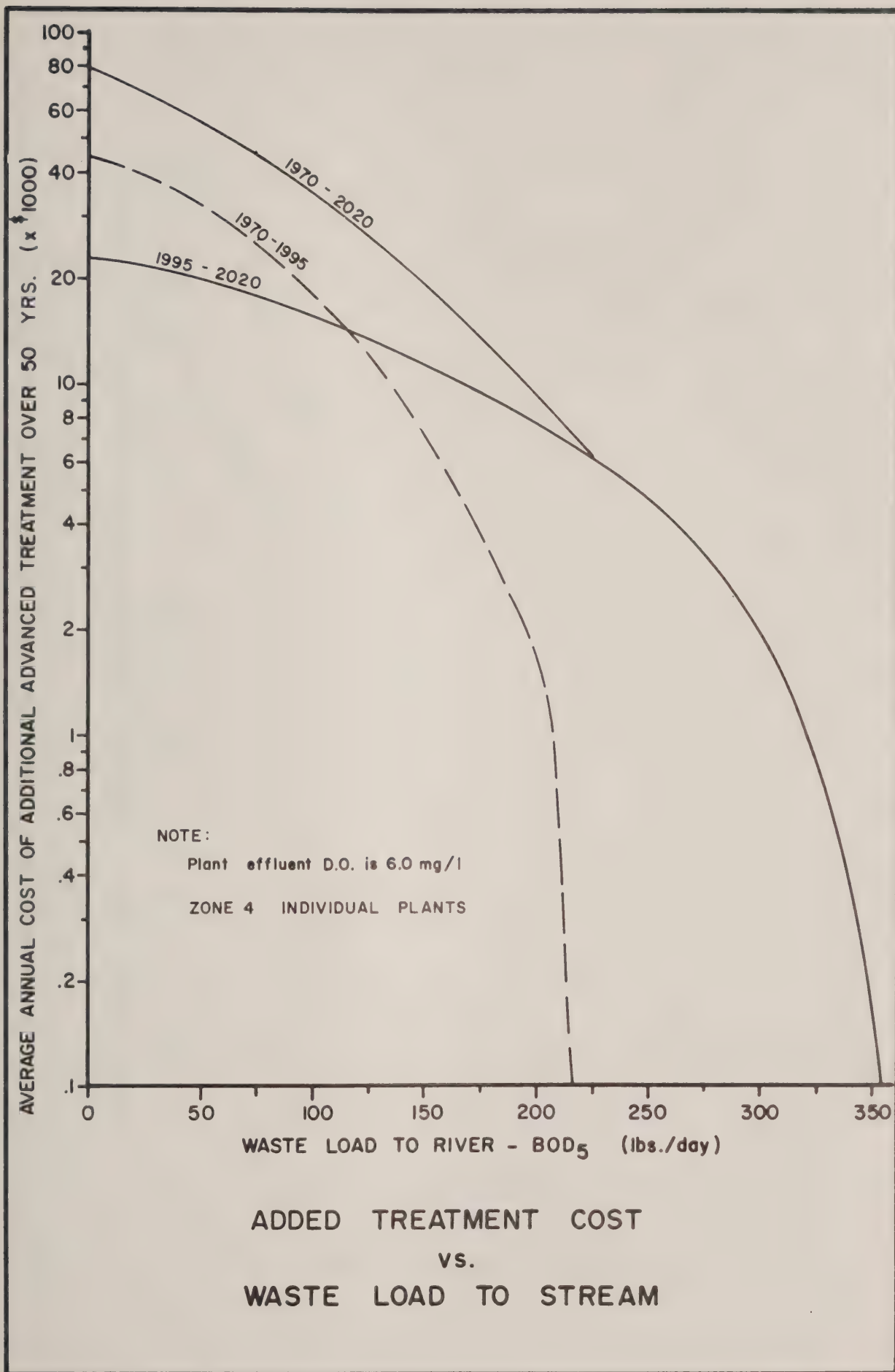
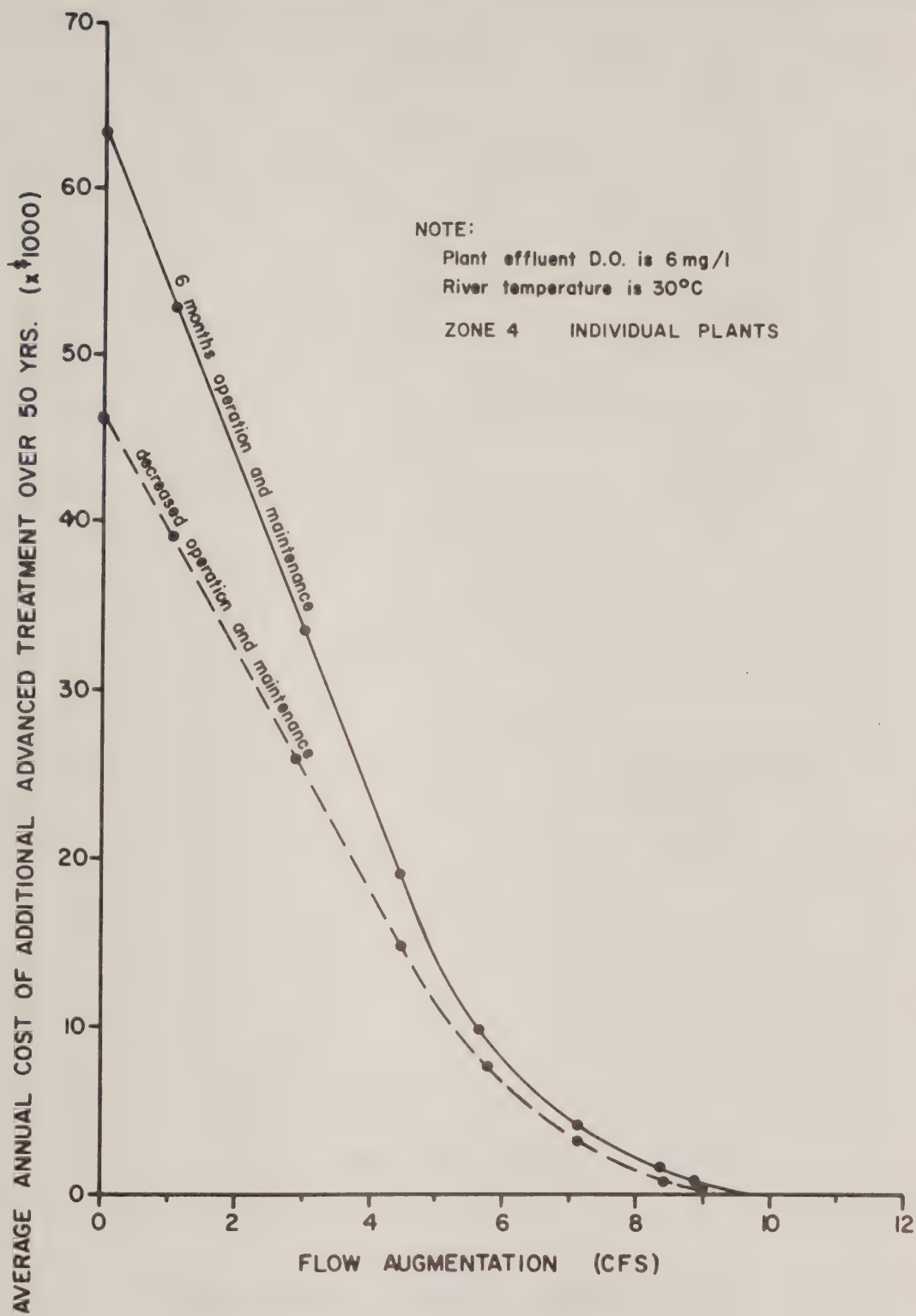
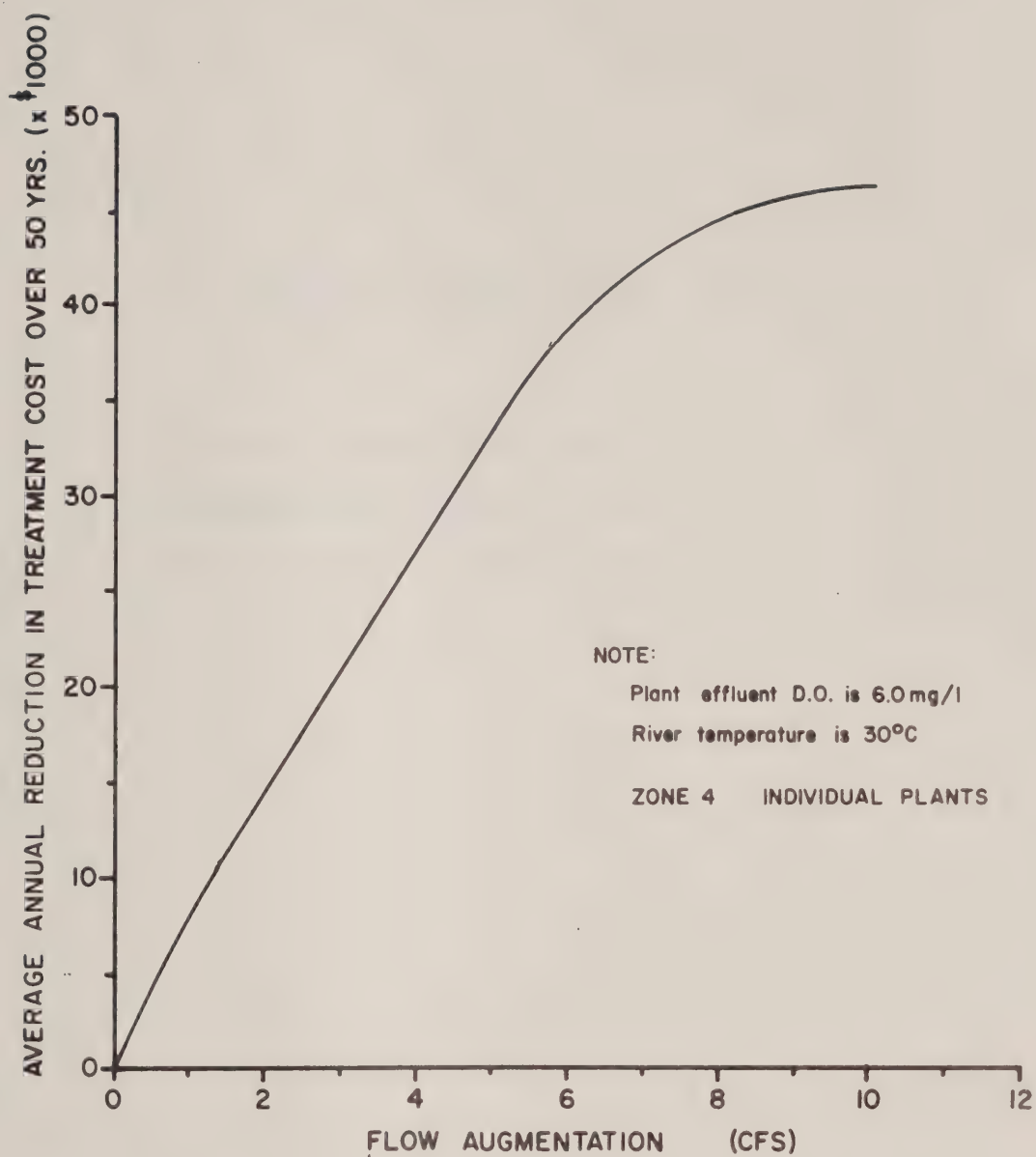


FIGURE EE-4



ADDED TREATMENT COST
vs.
FLOW AUGMENTATION



TREATMENT COST REDUCTION
vs.
FLOW AUGMENTATION

INDIVIDUAL TREATMENT PLANTS

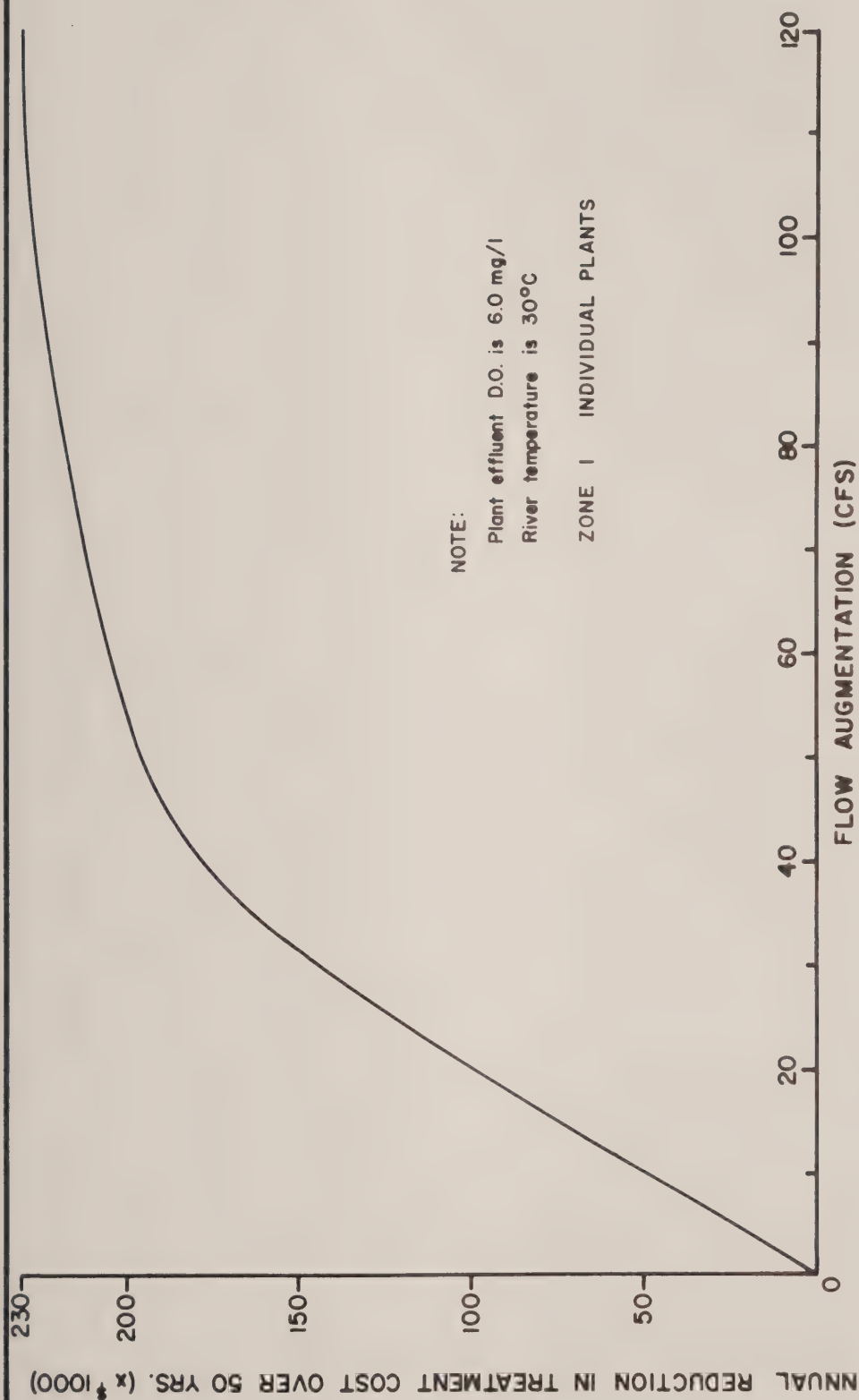
Curves of Average Annual Decrease
in Treatment Costs versus Flow Augmentation
and Table of Flow Augmentation Regimes

TABLE EE-2

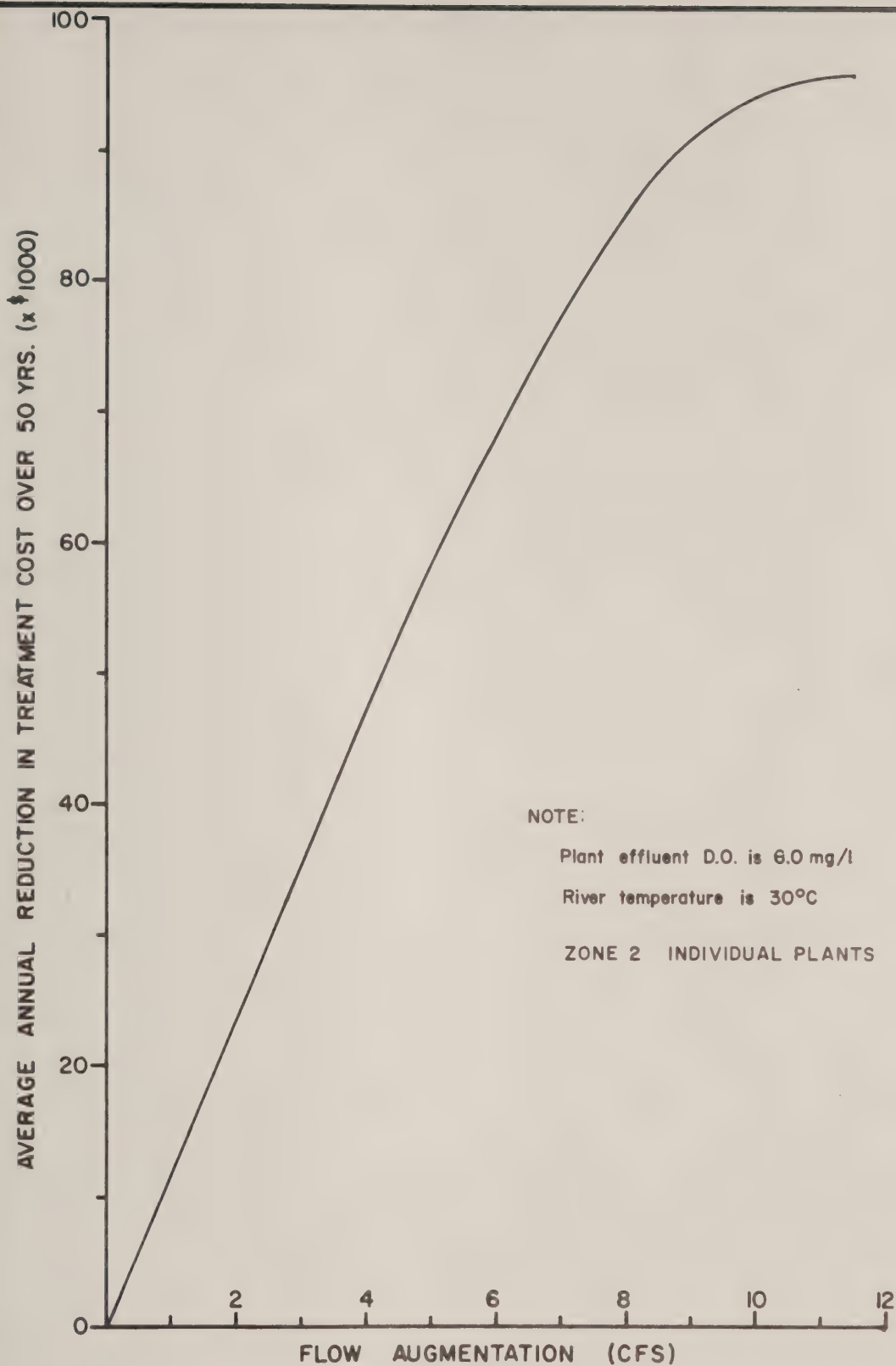
CHARLES RIVER WATERSHED STUDY

Flow Augmentation Regimes for Individual Treatment Plants

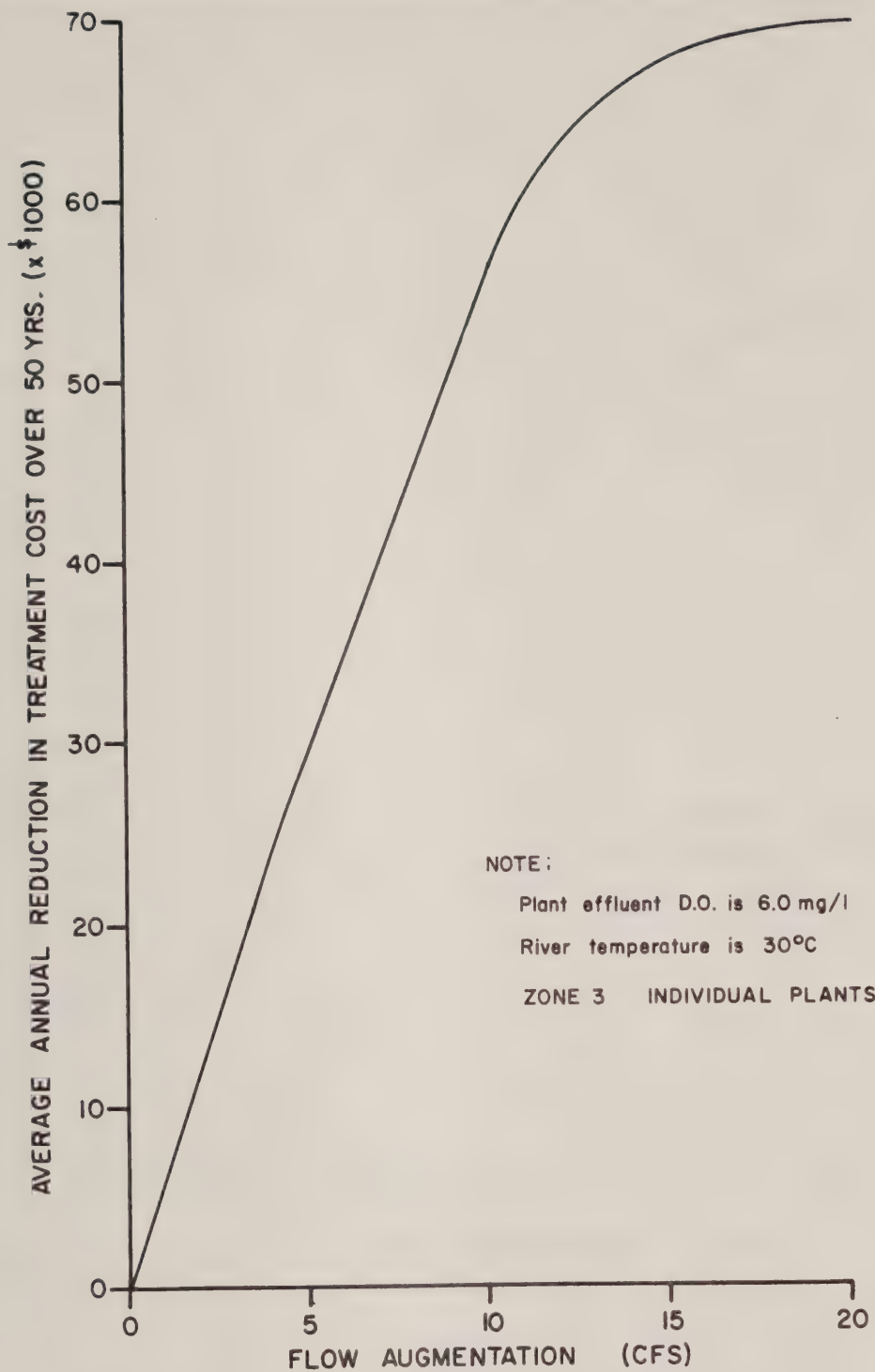
Zone	<u>Augmentation Ratio</u>					
	May (20°C)	June (25°C)	July (30°C)	Aug. (30°C)	Sept. (25°C)	Oct. (20°C)
1	.28Q _{I1}	.47Q _{I1}	Q _{I1}	Q _{I1}	.47Q _{I1}	.28Q _{I1}
2	.31Q _{I2}	.53Q _{I2}	Q _{I2}	Q _{I2}	.53Q _{I2}	.31Q _{I2}
3	.28Q _{I3}	.51Q _{I3}	Q _{I3}	Q _{I3}	.51Q _{I3}	.28Q _{I3}
4	.33Q _{I4}	.53Q _{I4}	Q _{I4}	Q _{I4}	.53Q _{I4}	.33Q _{I4}
5	.22Q _{I5}	.44Q _{I5}	Q _{I5}	Q _{I5}	.44Q _{I5}	.22Q _{I5}
6	.29Q _{I6}	.52Q _{I6}	Q _{I6}	Q _{I6}	.52Q _{I6}	.29Q _{I6}



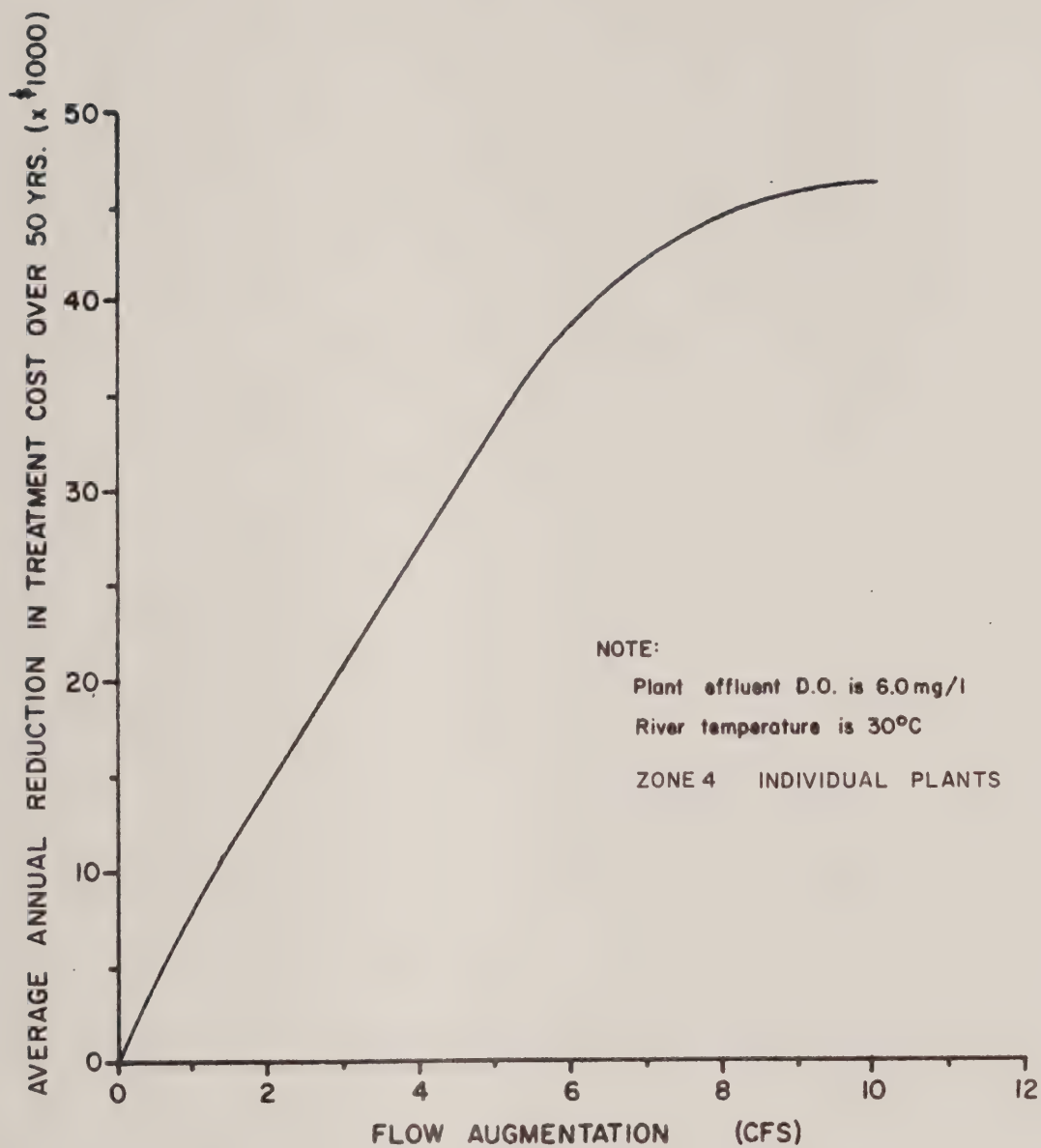
TREATMENT COST REDUCTION
 vs.
 FLOW AUGMENTATION



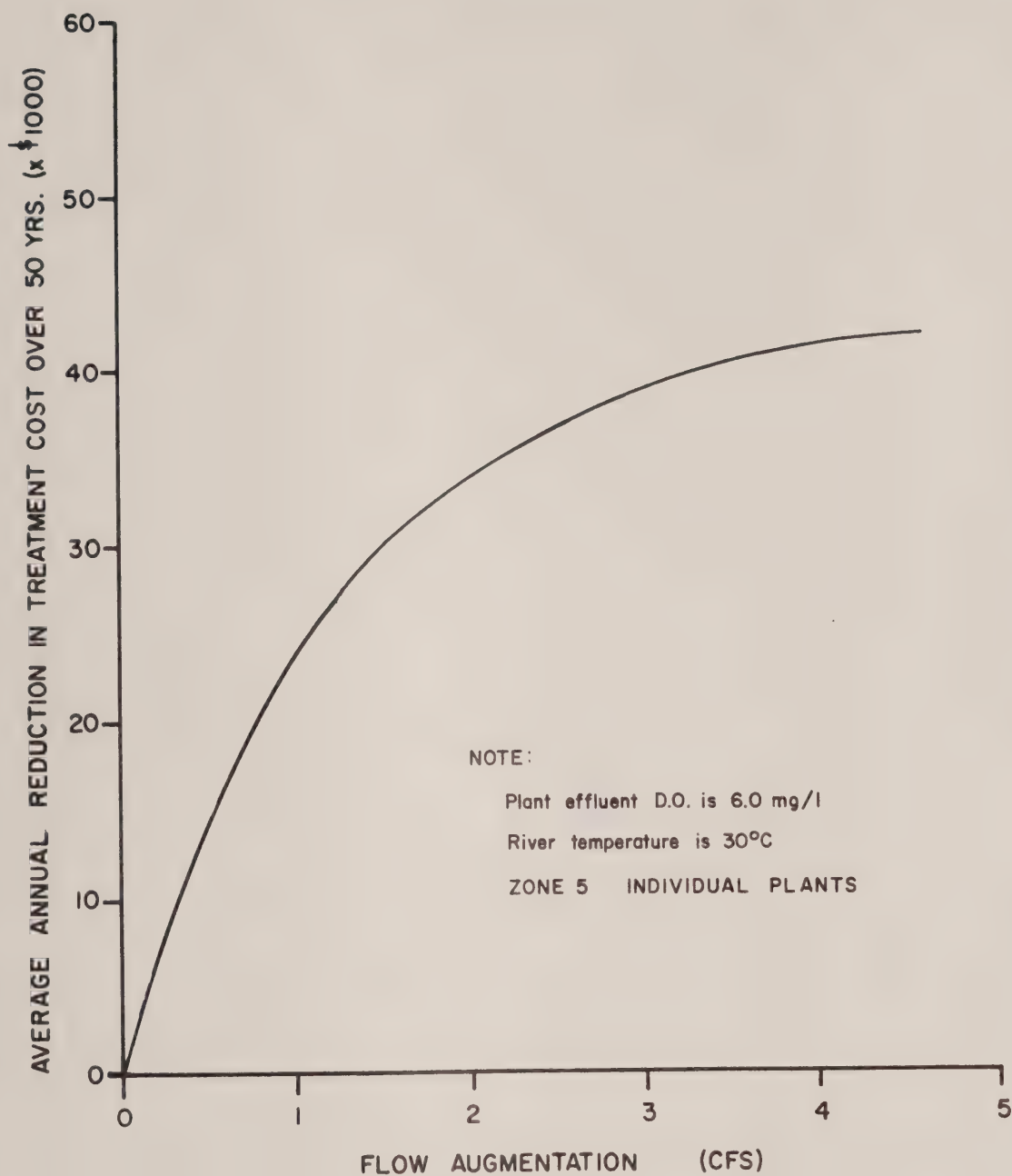
TREATMENT COST REDUCTION
vs.
FLOW AUGMENTATION



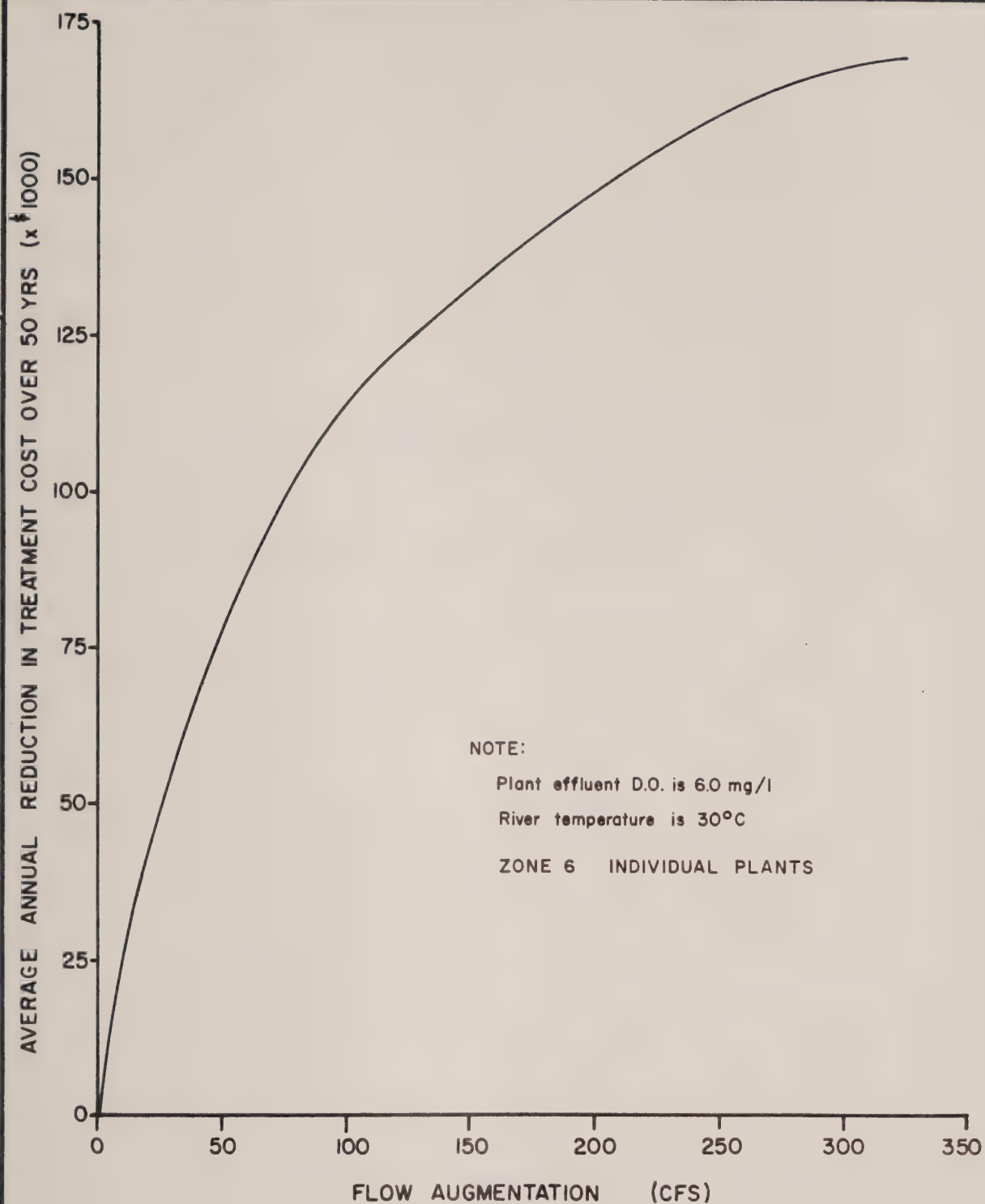
TREATMENT COST REDUCTION
vs.
FLOW AUGMENTATION



TREATMENT COST REDUCTION
vs.
FLOW AUGMENTATION



TREATMENT COST REDUCTION
vs.
FLOW AUGMENTATION



TREATMENT COST REDUCTION
vs.
FLOW AUGMENTATION

FIGURE EE-12

REGIONAL TREATMENT PLANTS

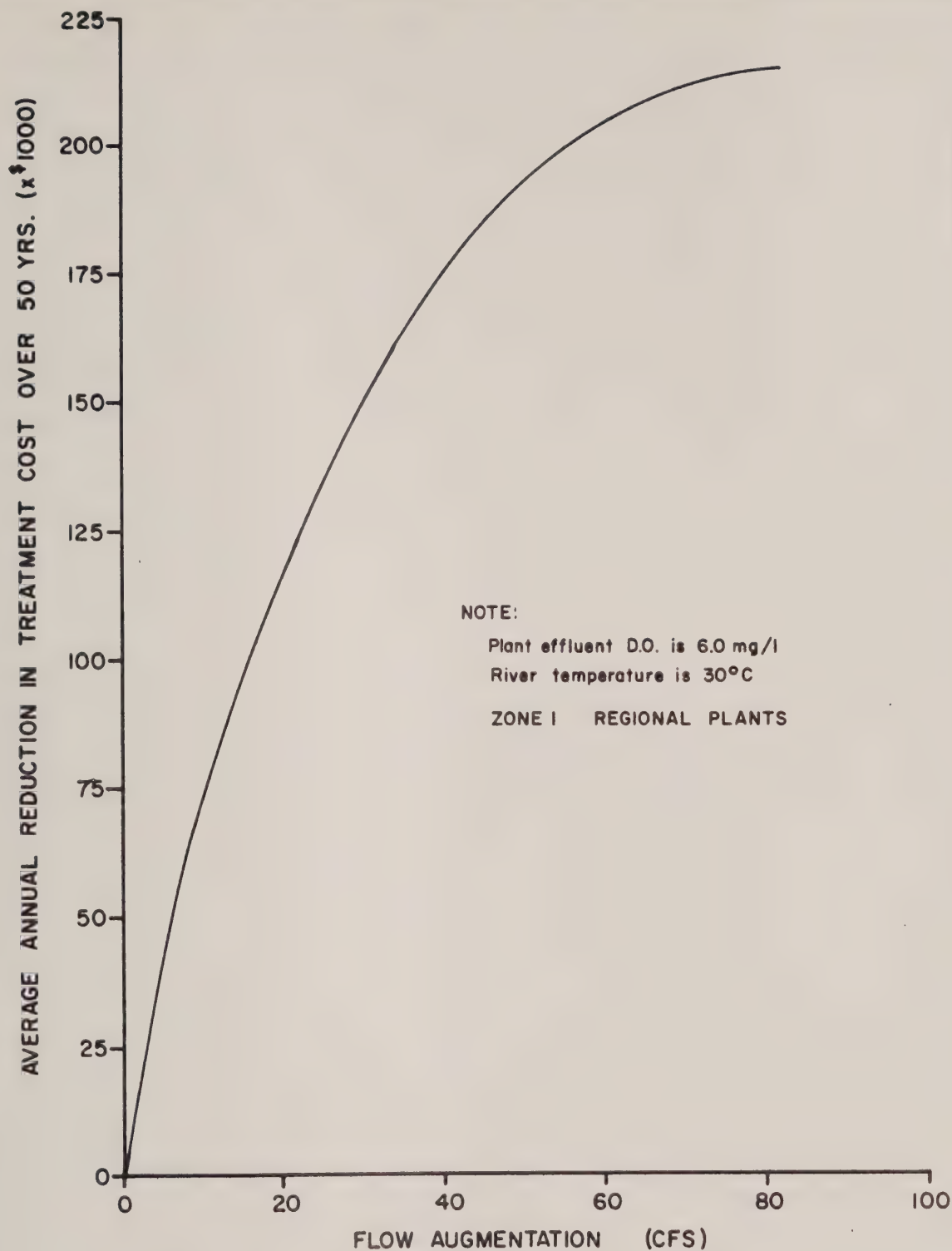
Curves of Average Annual Decrease
in Treatment Costs Versus Flow Augmentation
and Table of Flow Augmentation Regimes

TABLE EE-3

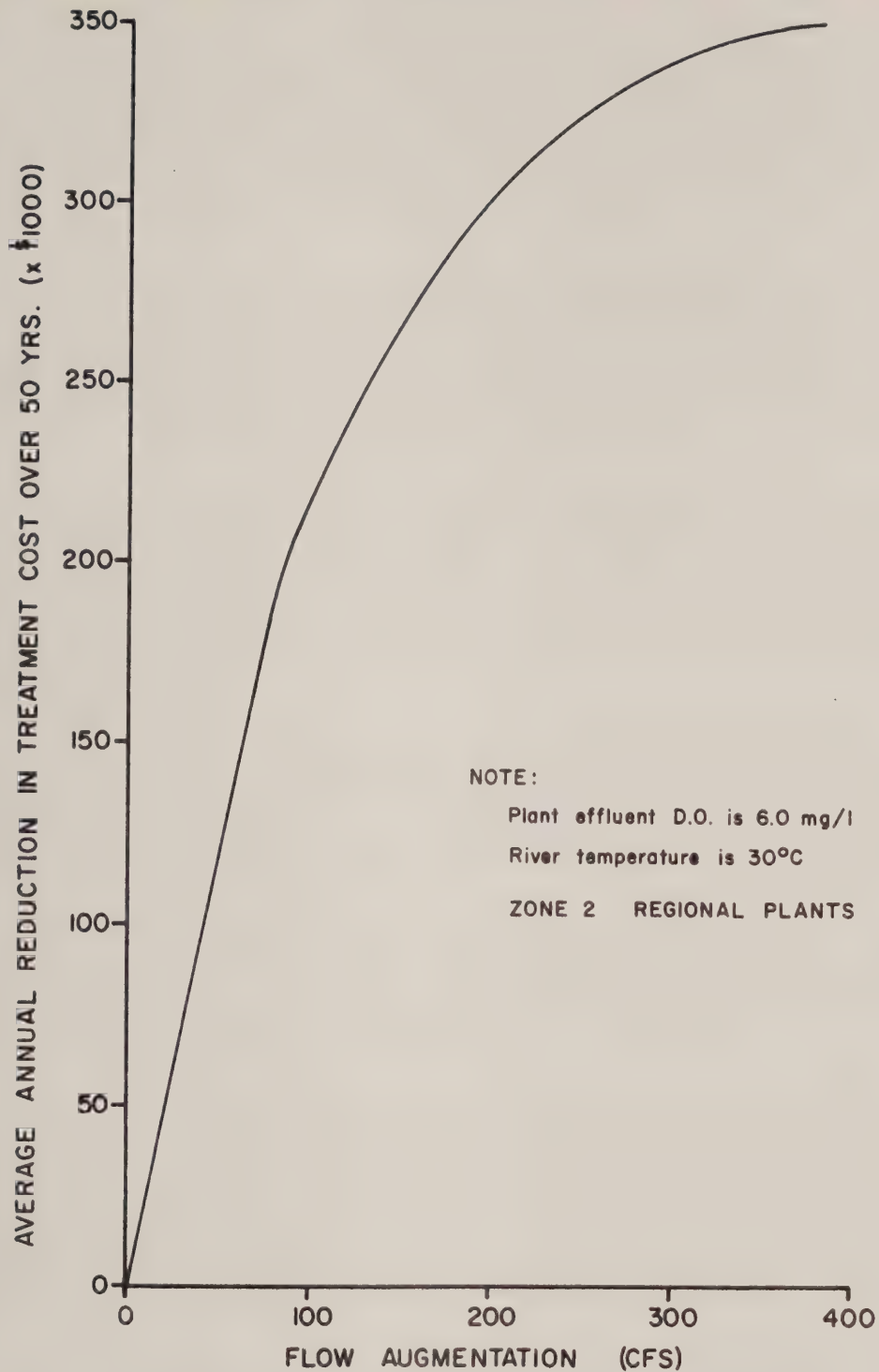
CHARLES RIVER WATERSHED STUDY

Flow Augmentation Regimes for Regional Treatment Plants

Zone	<u>Augmentation Ratio</u>					
	May (20°C)	June (25°C)	July (30°C)	Aug. (30°C)	Sept. (25°C)	Oct. (20°C)
1	.30Q _{R1}	.51Q _{R1}	Q _{R1}	Q _{R1}	.51Q _{R1}	.30Q _{R1}
2	.26Q _{R2}	.52Q _{R2}	Q _{R2}	Q _{R2}	.52Q _{R2}	.26Q _{R2}



TREATMENT COST REDUCTION
vs.
FLOW AUGMENTATION



TREATMENT COST REDUCTION
vs.
FLOW AUGMENTATION

2. Application

The information shown on the foregoing Figures EE-7 through EE-14 shows potential reductions in the cost of waste treatment due to varying flow augmentation regimes. Before the feasibility of flow augmentation in the Charles River Basin can be determined, it is necessary to relate this information to storage volumes and storage costs.

Augmentation flow, as computed in the model and as used herein, is the flow which when added to the base flow and the waste flow in a reach will provide a total flow capable of meeting the dissolved oxygen criteria. Base flow magnitudes are estimates of the lowest seven day average which could be expected on a frequency of once in ten years in the absence of waste flow.

Waste flow magnitudes vary with population growth, water consumption and type of sewerage system. Waste flow is derived primarily from the water supply systems of the area, but is also affected by ground water infiltration to sewer systems. A major increase in waste flow, therefore, presupposes an increase in water supply. Estimated base flows and waste discharge flows for the basin are given in Table EE-4.

The relationship between base flow, waste flow and augmentation flow is illustrated in Table EE-5. It shows flows in Zone 4 corresponding to a flow augmentation regime of 5 cfs in 1995 and 2020. This regime, as indicated in Figure EE-4, would result in an estimated average annual savings of \$33,500 over a fifty year period.

Table EE-5 indicates the waste flow increase accounts for the increase in total flow while the augmentation flow and base flow regimes remain unchanged. The water quality storage requirements can, therefore be examined independently of increased waste flow and water supply requirements, if desired.

To determine the amount of reservoir storage needed to meet a selected flow regime, a comparison of that regime with either historic flows, or synthetic flows representing a critical design period, is required. This can be done in the case of water quality storage amounts and costs, provided the historic or synthetic hydrograph is adjusted for changing waste flows. An illustration of how this may be done is shown in Table EE-6, again using Zone 4 as an example.

Once the storage amount is established, the associated cost of reservoir construction and operation can be estimated with allowance for the needs of other purposes using standard project formulation procedures. Several flow augmentation regimes may be tested in this

way and a storage cost versus flow augmentation curve prepared. This curve when compared with the treatment cost reduction versus flow augmentation curve can be used to determine the optimum economic mix of advanced waste treatment and water control storage.

TABLE EE-4
CHARLES RIVER WATERSHED STUDY
Base Flows and Waste Flows¹

Zone	Base Flow (cfs)	Waste Flow (cfs)		
		1965	1995	2020
Individual Plants				
1	0.2	2.4	6.0	13.4
2	0.2	2.1	5.9	14.7
3	0.2	0.5	1.7	5.4
4	0.2	0.6	0.9	2.5
5	0.2	0.0	1.4	3.1
6	1.5	1.5	5.5	14.1
Regional Plants				
1	0.2	2.4	5.0	10.4
2	2.3	4.7	16.4	42.8

1. Flows shown are those which originate within a zone.

TABLE EE-5

CHARLES RIVER WATERSHED STUDY

5 cfs Flow Augmentation Regime - Zone 4

Month	Base	Flow (cfs)		Total
		Waste	Augmentation	
<u>1995</u>				
May	0.2	0.9	1.6	2.7
June	0.2	0.9	2.6	3.7
July	0.2	0.9	5.0	6.1
August	0.2	0.9	5.0	6.1
September	0.2	0.9	2.6	3.7
October	0.2	0.9	1.6	2.7
<u>2020</u>				
May	0.2	2.5	1.6	4.3
June	0.2	2.5	2.6	5.3
July	0.2	2.5	5.0	7.7
August	0.2	2.5	5.0	7.7
September	0.2	2.5	2.6	5.3
October	0.2	2.5	1.6	4.3

TABLE EE-6

CHARLES RIVER WATERSHED STUDY

Sample Storage Computation for 5 cfs Flow Augmentation¹

Zone 4

Month	Historic Total Flow ²	Estimated Waste Flow (1965)	Historic Natural Flow	Augmentation Plus Base Flow	Water Quality Storage Releases ³
May	8.50	0.60	7.90	1.80	-
June	5.00	0.60	4.40	2.80	-
July	1.80	0.60	1.20	5.20	4.00
August	0.90	0.60	0.30	5.20	4.90
September	1.00	0.60	0.40	2.80	2.40
October	1.50	0.60	0.90	1.80	0.90
					<u>12.20</u>

12.20 MSF x 60.4 = 737 Acre Feet

1. All figures are in month-second-feet which is a volume of water equivalent to a flow of one cubic foot per second for one month.
2. Historic Total Flow figures are for illustrative purposes only.
3. Does not include amounts for reservoir evaporation, transit losses and regulation losses.

ATTACHMENT EF

SUBSURFACE DISPOSAL OF WASTE

1. General

If the soil has good permeability, subsurface disposal of wastes after secondary treatment and chlorination can offer an economical way of meeting water quality goals.

There are two common methods of subsurface disposal; namely, direct injection into the groundwater through recharge wells, and spreading or distributing the waste on the ground surface and allowing it to seep into the soil. The injection method has several disadvantages over spreading. High levels of treatment may be required prior to injection to avoid clogging of the recharge well. The removal of pollutants from the waste as it travels through the soil to the groundwater by the spreading method is negated by direct injection. Unless land costs are extremely high, groundwater injection is usually more expensive than spreading.

Disadvantages of waste water spreading are the relatively high land requirements and possible operational problems during periods of high water table and during the winter months.

Percolation through the ground has been shown to be an effective mechanism for the removal of pollutants from wastewater. Studies at wastewater reclamation projects have shown that vertical percolation of wastewater through relative short distances is effective in removing bacteria and virus, BOD₅, suspended solids and phosphate ion.

Care should be taken to insure wastewater spreading does not interfere with groundwater supplies, although in sections of the country where water is scarce, this technique is being used as a method of wastewater reuse for water supply. In New England where sufficient water is available to avoid reclaiming sewage effluents, wastewater reuse would probably be unacceptable to the general public.

2. Land Requirements

The land requirement is directly proportional to the waste flow and inversely proportional to the rate of infiltration. The infiltration rate for a given soil is affected by depth to water table, time in the spreading cycle and type of treatment applied to the waste. For wastewater spreading to be successful, the soil must have a good permeability.

The U.S. Geological Survey is presently conducting water resources investigations of the Charles River Watershed. Part of the study includes describing the surficial geology of the area. Preliminary results indicate the existence of many lenses of sand and gravel located near the riverbank that may be suitable for wastewater spreading. In some cases the depth to groundwater may

be as much as thirty to forty feet. At these locations, it may be possible to discharge treated effluent over spreading basins which would percolate vertically to the groundwater table and then horizontally to a nearby watercourse.

Land requirements to handle the 1995 to 2020 waste flows at assumed infiltration rates of 0.5 fpd (feet per day) and 2.0 fpd are presented on Table EF-1. In the analysis, it was assumed that each spreading basin will be operated eight hours per day and then allowed to aerate, the minimum number of spreading basins is three, and the total land requirement for spreading is 1.25 times the spreading basin area requirement.

3. Cost of Wastewater Spreading

The cost of spreading is affected mainly by the percolation rate through the soil which is the major factor in determining the land requirement. Infiltration rate is affected by depth to water table, time in the spreading cycle, and type of treatment applied to the waste.

Cost analyses, based on procedures noted in Reference 26, have been made which illustrate the variations in cost for a given waste flow at different rates of infiltration. In the analyses, the following assumptions were made:

- (a) The cost of land is \$2,000 per acre.
- (b) Each spreading basin will be operated eight hours per day and then allowed to aerate (considered optimum for spreading application).
- (c) The minimum number of spreading basins is three.
- (d) Total land requirement for spreading operation is 1.25 times the spreading basin area requirement.
- (e) Cost of construction, excluding dike construction, is \$1,600 per acre of spreading basin.
- (f) Cost of dike construction is \$0.59 per cubic yard.
- (g) Dike cross-section is eight square yards.
- (h) Spreading ponds are square in shape.
- (i) Costs of engineering and contingencies are equal to 0.25 times the cost of construction.

TABLE EF-1

CHARLES RIVER WATERSHED STUDY
Acreage Requirement for Wastewater Spreading
Upper Charles River Communities

Community	1995 Waste Flow (mgd)	Acres Required (Infiltration Rate = 0.5 fpd)	Acres Required (Infiltration Rate = 2.0 fpd)	2020 Waste Flow (mgd)	Acres Required (Infiltration Rate = 0.5 fpd)	Acres Required (Infiltration Rate = 2.0 fpd)
Milford	3.2	74	18	6.7	155	39
Bellingham	.65	15	3.8	1.9	54	14
Franklin	3.8	89	22	9.5	220	55
Medway	.7	16	4.0	1.7	39	9.8
Wrentham	1.1	25	6.2	3.5	80	20
Norfolk	.6	13	3.2	1.6	37	9.2
Millis	1.2	27	6.8	2.7	62	15
Medfield	1.5	34	8.5	4.3	98	24
Holliston	.9	20	5.0	2.0	46	12
Sherborn	.1	2.1	.5	.4	8.8	2.2
Total	13.75	315	78	34.3	800	200

- (j) Maintenance cost is \$300 per acre of spreading basin per year.
- (k) All costs are based on an interest rate of 4-5/8 percent, amortized over 25 years and adjusted to the June 1967 level.
- (l) Two rates of infiltration are assumed--0.5 fpd and 2.0 fpd.

Based on the above assumptions, curves of average annual cost of wastewater spreading for two infiltration rates versus wastewater flow have been plotted (Figure EF-1). The curves do not reflect the cost of providing the preliminary treatment. Prior to wastewater spreading, primary and secondary treatment and chlorination should be sufficient. However, the coagulation and sedimentation process may be desirable as an additional pretreatment step. Coagulation and sedimentation would further reduce the amount of suspended materials from the wastewater and increase the efficiency of the spreading application. This may be reflected in the ability to achieve higher infiltration rates and thus require less land.

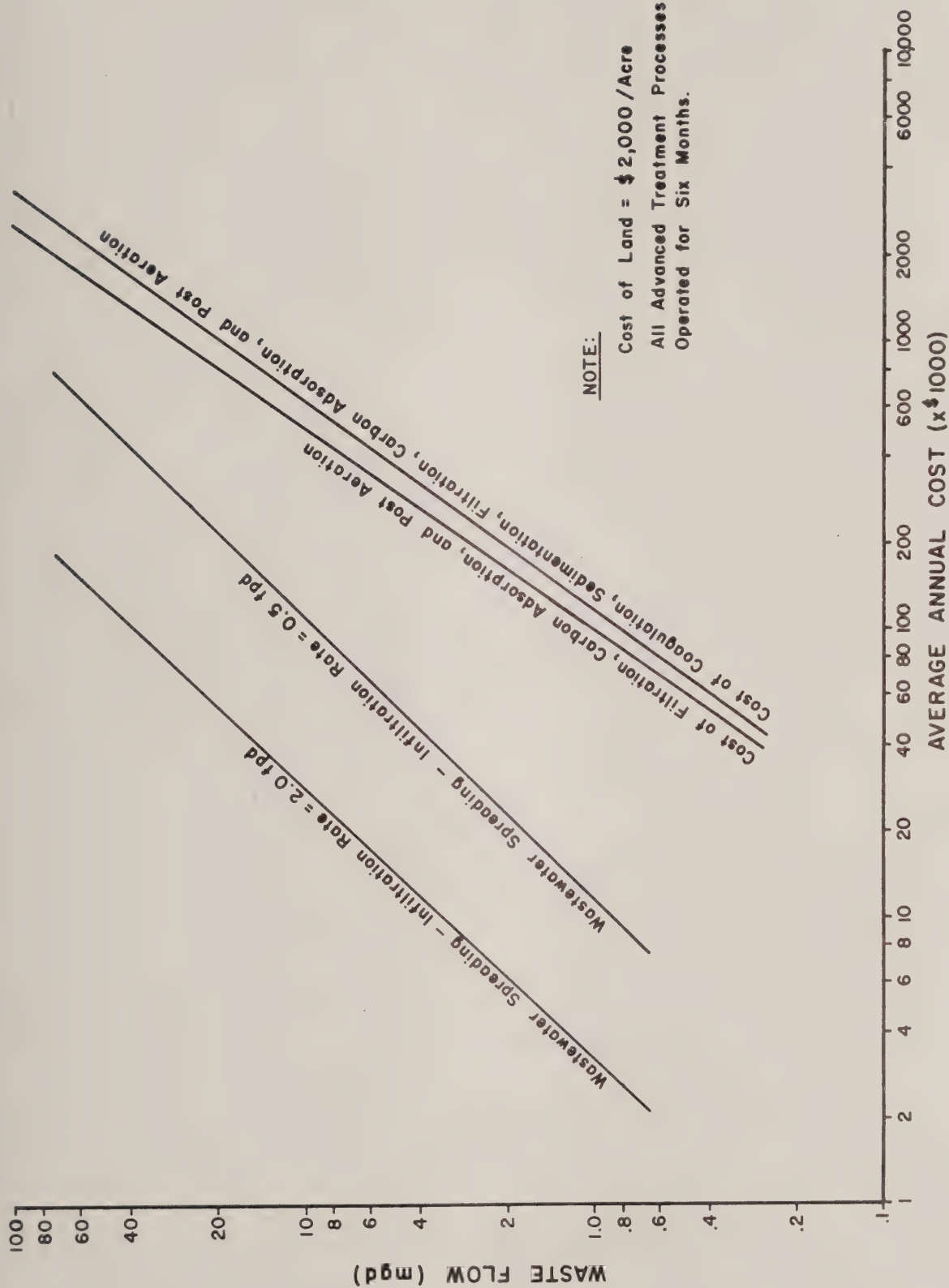
As indicated previously, to meet water quality goals by advanced waste treatment, the municipalities would typically have to provide the equivalent of primary treatment, secondary treatment, coagulation, sedimentation, filtration, carbon adsorption, and post-aeration. The average annual cost of advanced waste treatment processes as a function of waste flow is also shown on Figure LF-1. It is evident from Figure EF-1 that substantial savings can result where wastewater spreading proves feasible.

Based on the projected waste flows of each community and Figure EF-1, costs of wastewater spreading at the two assumed infiltration rates were computed for the 1970 to 1995, and 1995 to 2020 time periods and are shown on Table EF-2. It will be noted that increased infiltration rates significantly decrease the land requirements and, therefore, the cost.

During periods of high groundwater table or during the winter when the efficiency of wastewater spreading may be reduced, the treated effluent may be discharged directly to the surface water. These periods generally correspond to the same times when operation of advanced treatment processes may not be needed.

4. Summary

Subsurface disposal of treated waste by spreading may offer an economical means of meeting water quality standards and should be considered by the upper Charles River communities. This method of waste treatment will require detailed engineering investigations, such as extensive borings and percolation tests at proposed spreading sites prior to its use.



NOTE:

Cost of Land = \$2,000 /Acre

All Advanced Treatment Processes
Operated for Six Months.

AVERAGE ANNUAL COST OF TREATMENT VS. WASTE FLOW

TABLE EF-2

CHARLES RIVER WATERSHED STUDY

Average Annual Cost of Wastewater Spreading

Community	1995 Waste Flow (mgd)	Inf. Rate 0.5 fpd Average Annual Cost 1970 - 1995	Inf. Rate 2.0 fpd Average Annual Cost 1970 - 1995	2020 Waste Flow (mgd)	Inf. Rate 0.5 fpd Average Annual Cost 1995 - 2020	Inf. Rate 2.0 fpd Average Annual Cost 1995 - 2020
Milford	3.2	\$38,000	\$10,000	6.7	\$75,000	\$20,000
Bellingham	.65	7,500	2,200	1.9	22,000	6,000
Franklin	3.8	44,000	12,000	9.5	105,000	27,000
Medway	.7	8,300	2,300	1.7	20,000	5,400
Wrentham	1.1	13,000	3,600	3.5	40,000	11,000
Norfolk	.6	7,100	2,000	1.6	18,000	5,000
Millis	1.2	14,000	3,800	2.7	31,000	8,300
Medfield	1.5	17,000	4,800	4.3	49,000	13,000
Holliston	.9	11,000	2,900	2.0	26,000	6,200
Sherborn	0.0	0	0	.4	4,800	1,400
Total	13.65	\$159,900	\$43,600	34.3	\$390,800	\$103,300

WATER RESOURCE INVESTIGATION

CHARLES RIVER STUDY

APPENDIX F

IMPOUNDMENTS AND TRIBUTARY WATERSHEDS

Prepared by

U. S. DEPARTMENT OF AGRICULTURE

Soil Conservation Service
Economic Research Service
Forest Service

DECEMBER 1971

I

PREFACE

The basic objective of the Charles River Watershed Study has been the formulation of a plan of development which will serve as a guide for the best use, or combination of uses, of water and related land resources in the watershed to meet foreseeable short and long term needs. The Corps of Engineers has been assigned the major responsibility for the accomplishment of the study. The Department of Agriculture has been a member of the Charles River Study Coordinating Committee and close coordination has been maintained with the Corps of Engineers throughout the study.

The following Appendix F is an abridged version of the Charles River Study Area Report prepared under the Massachusetts Water Resources Study (Type IV, River Basin). This study is a cooperative endeavor by the United States Department of Agriculture and the Massachusetts Water Resources Commission. Some of the items studied in upstream watersheds of the Commonwealth are: identification of potential reservoir sites; appraisal of damage from floodwater, sediment, and erosion; present and projected land use; fish and wildlife, recreation, water supply, water quality, and identification of flood plains and wetlands.

Results of these studies on the Charles River Watershed, made primarily in the area upstream of the South Natick Dam, Town of Natick, are presented in this report prepared by the Soil Conservation Service, the Economic Research Service, and the Forest Service of the United States Department of Agriculture and the Massachusetts Water Resources Commission. Information and assistance were provided by the Division of Fisheries and Game, Division of Forests and Parks and Division of Conservation Services of the Massachusetts Department of Natural Resources.

The Massachusetts Water Resources Commission will use this report, together with other reports and studies prepared by the United States Department of Agriculture and others, in the preparation of a comprehensive plan for the Commonwealth's water and land resources.

Information and data contained herein will also assist State agencies, towns, regional planning groups, and other interested persons or groups in developing project plans for the preservation, conservation, development, and utilization of the land and water resources of Massachusetts.

APPENDIX F
TRIBUTARY WATERSHEDS
TABLE OF CONTENTS

<u>Chapter Number</u>	<u>Description</u>
1.	SUMMARY
2.	DESCRIPTION
3.	LAND USE
4.	FLOOD DAMAGES
5.	EROSION AND SEDIMENT
6.	RECREATION
7.	FISH AND WILDLIFE
8.	WATER SUPPLY AND IRRIGATION
9.	DRAINAGE
10.	WETLANDS
11.	WATER QUALITY AND POLLUTION
12.	LAND TREATMENT AND MANAGEMENT

1.1 General

This report presents data and information gathered or developed by the U. S. Department of Agriculture for the Charles Study Area. In addition to providing information to the Coordinating Committee for use in the Charles River Watershed Comprehensive Study, a report will be furnished to the Massachusetts Water Resources Commission as a contribution to the Massachusetts Water Resources Type IV River Basin Study.

Based on the investigations made, and data collected and analyzed, certain conclusions were reached by the Study Team. Also, some of these conclusions resulted in recommendations for action by local or state agency or board.

1.2 Conclusions and Appropriate Recommendations

1.21 Flooding

Floodwater damages are not considered significant at this time in the Tributary Watersheds of the Charles. Without proper flood plain management, land treatment, and the protection of the remaining natural flood storage areas (usually existing wetlands), the growing urbanization of this watershed will result in increasing flood damages. Based upon present conditions, structural measures, such as floodwater retarding structures, dikes and channel improvement were not found to be practical or feasible.

1.22 Flood Plain Management

Proper flood plain management will tend to prevent future encroachment of existing flood plains. Some programs that are being used to present this encroachment are the Massachusetts Inland Wetlands Protective Act, the Hatch Act, and local zoning and regulation by individual towns, or by a special act of the General Court. Developments constructed on flood plains create nuisance-type flooding problems, sewerage blockages, etc., frequently throughout the year. Local town officials must do all in their power to prevent such developments on low lands, as well as prevent the filling of valuable and necessary flood plains and natural detention basins. Strict enforcement of the Hatch Act could be a partial solution to this encroachment problem, but state agencies involved must be made aware of proposed developments in order to provide effective controls or restrictions.

Towns within the Commonwealth are now being encouraged and assisted by governmental agencies in the management and regulation of flood plain areas. The Town of Norfolk has applied for flood insurance through the Flood Insurance Administration, U. S. Housing and Urban Development, and the Towns of Franklin, Medfield, Medway, Newton, and Westwood have inquired about such insurance. Other towns should apply for this flood insurance program to assist owners of existing properties within the flood plains which are subject to flooding. Towns can use flood plain zoning, outright purchase of flood plains in fee, purchase of easements, and zoning so as to encourage low intensity and compatible use. In addition, towns can assist and encourage in the implementation of the Inland Wetland Protection Act.

Special emphasis needs to be given to the preparation of flood plain delineation maps and stream flood profiles for use by towns in their flood plain zoning and management. In addition, assistance is needed by state and federal agencies to the towns in the preparation of applicable flood plain regulations, zoning by-laws, restrictions or other means to prevent undue encroachment of the town's flood plains.

1.23 Open Space

Projections indicate that agricultural land (cropland and grassland) and idle land almost disappear as land uses and forest land is significantly reduced by the year 2020. This is due to increased urban pressures on the land resource base. With this decrease in agricultural land, there is a corresponding decrease in the amount of open space and natural areas, as well as in the amount of forestland. Open space areas (land not devoted primarily to urban use) must be maintained. Some type of acquisition or restriction program is needed to assure that this open space will be available for use and enjoyment in the future.

Concerted effort is needed by state and local governments to assure that a minimum amount of agricultural land (cropland and grassland) will be maintained and used and that forest land be protected and utilized for the benefit of communities and state. Open space areas will help maintain the present level of environmental quality, and provide a diversity of land use. The seven conservation areas, as shown on Figure 4, should be acquired or preserved as soon as practical. Not only will these seven areas preserve and provide open space, but will preserve additional natural wetland and flood detention areas. The acquisition or restriction should be coordinated with the Massachusetts Department of Natural Resources' work under the Inland Wetland Act, as well as the Self-Help program and Bureau of Outdoor Recreation Programs.

State and Federal Agencies should give high priority, and maximum financial assistance, to towns in their efforts to implement their local conservation programs.

1.24 Recreation

Recent studies by the Bureau of Outdoor Recreation, Department of Interior, have shown that there is a shortage of outdoor recreational areas in Massachusetts. This is further shown in the new Massachusetts Outdoor Recreation Environmental Conservation Plan prepared by the Massachusetts Department of Natural Resources. This shortage is particularly evident in the area in and surrounding the highly populated Greater Boston Area. Needed are areas for picnicking, camping, swimming, hunting, boating, nature study, and hiking.

The four conservation pools with potential for recreation offer a means to satisfy part of this demand for outdoor recreation and should be installed, operated, and maintained. Also, applicable recreation facilities for picnicking, camping, swimming, and boating should be installed at the appropriate sites. These sites, with potential uses, are shown on Figure 4.

Proper land management and treatment measures can provide opportunities for recreational developments and a landscape pleasing to the traveling public.

1.25 Fish and Wildlife

Additional public areas are needed for coldwater and/or warmwater fishing, as well as for wildlife habitat development. Reservoirs installed for water based recreation also offer opportunities for fish and wildlife multiple-uses. The potential recreational sites should be managed for either coldwater or warmwater fisheries.

Future consideration might be given to allow fishing in Site 905 (Echo Lake). This will require special permission to allow fishing in a water supply reservoir. Also, there will need to be established a priority on water use and if water supply is of the highest priority, any other recreational uses should be approached in a manner that recognizes those uses are subservient to the primary water use.

1.26 Wetlands

Loss of wetlands by some type of development is a major problem in the tributary Watersheds of the Charles. These wetlands are valuable not only for open space areas, but for flood storage, habitat for various kinds of wildlife, and to improve the environmental quality. The "Inland Wetlands" Act provides a means whereby the Commonwealth can restrict and conserve inland wetland areas. Special emphasis is being given to this program to conserve and preserve the existing wetlands within the Charles Study Area.

All major wetland areas, as identified by the Massachusetts Department of Natural Resources, will be restricted and filling, draining, or building should be rigidly controlled in these areas. Towns within the Charles Study Area should assist the Massachusetts Department of Natural Resources in the restriction of these wetlands. Towns should also give these areas high priority in their plans for the development of the towns' natural resource program.

1.27 Reservoir Site Study

Forty-seven potential reservoir sites were identified in the September 1968 Report, "U.S.D.A. Interim Memorandum Number 1, Charles River Study." Further study of potential uses; recreation, fish, wildlife, low flow augmentation for water quality, etc.; reduced the number of potential sites to twelve. These remaining sites were presented to the Charles River Study Coordinating Committee, the Citizens Advisory Committee, and the general public at Town Informational Meetings (Note: These Town Informational Meetings were held in most Upper Charles River towns to inform local people of the Study's findings and to stimulate local comment on the Study's proposals.) Five potential sites were retained. From engineering and environmental points of view, the sites are far from ideal, however, the need for recreational bodies of water is great and may be greater than the detrimental effects of the shallow warm water pools created. The seven sites, eliminated at this time, were dropped to eliminate conflicts with the Corps' Natural Valley Storage proposal or because of local opposition. Two engineering studies have indicated that a potential exists on Mine Brook in Franklin for a water supply reservoir. Site 912 on Mine Brook may be considered a water supply potential and therefore is being allowed to overlap natural valley storage Area 0 since domestic water supply is acknowledged as being the highest and best use of water. During the implementation phase of acquiring the natural valley storage areas, the decision will be made as to whether to construct a water supply reservoir or to preserve the area in its natural condition in perpetuity.

Present authorizations of the U.S.D.A. Soil Conservation Service do not provide for a program for installation of impoundments in projects where flood prevention is not a primary purpose. Therefore, any installation of the proposed sites will have to be accomplished by state, local or private interests.

1.28 Town Soils Information

Conservation District should give high priority for assistance to towns within the Charles Study Area in their Town Natural Resources Programs, including completion of Town Soils Reports.

Before approval of development proposals by local boards, the soil limitations for the proposed use should be determined to assure that the proposed use is compatible with the soils condition at the site. In the event that the proposed use is limited by the soils, the local board should make sure that proper measures are included in the proposal to overcome the limitations or the development relocated to a more suitable site.

1.29 Land Management

Problems associated with agricultural land are not considered to be of major importance.

Erosion from agricultural and forest land was determined to be insignificant; however, erosion resulting from urban development is a major source of sedimentation. By placing proper emphasis on conservation practices during preparation of development plans, sediment production can be decreased.

Land managed and improved for more than one use will provide a diversity of resources and opportunities for man and a better environment to live in.

Needs for drainage works of improvement on agricultural land is considered a minor problem.

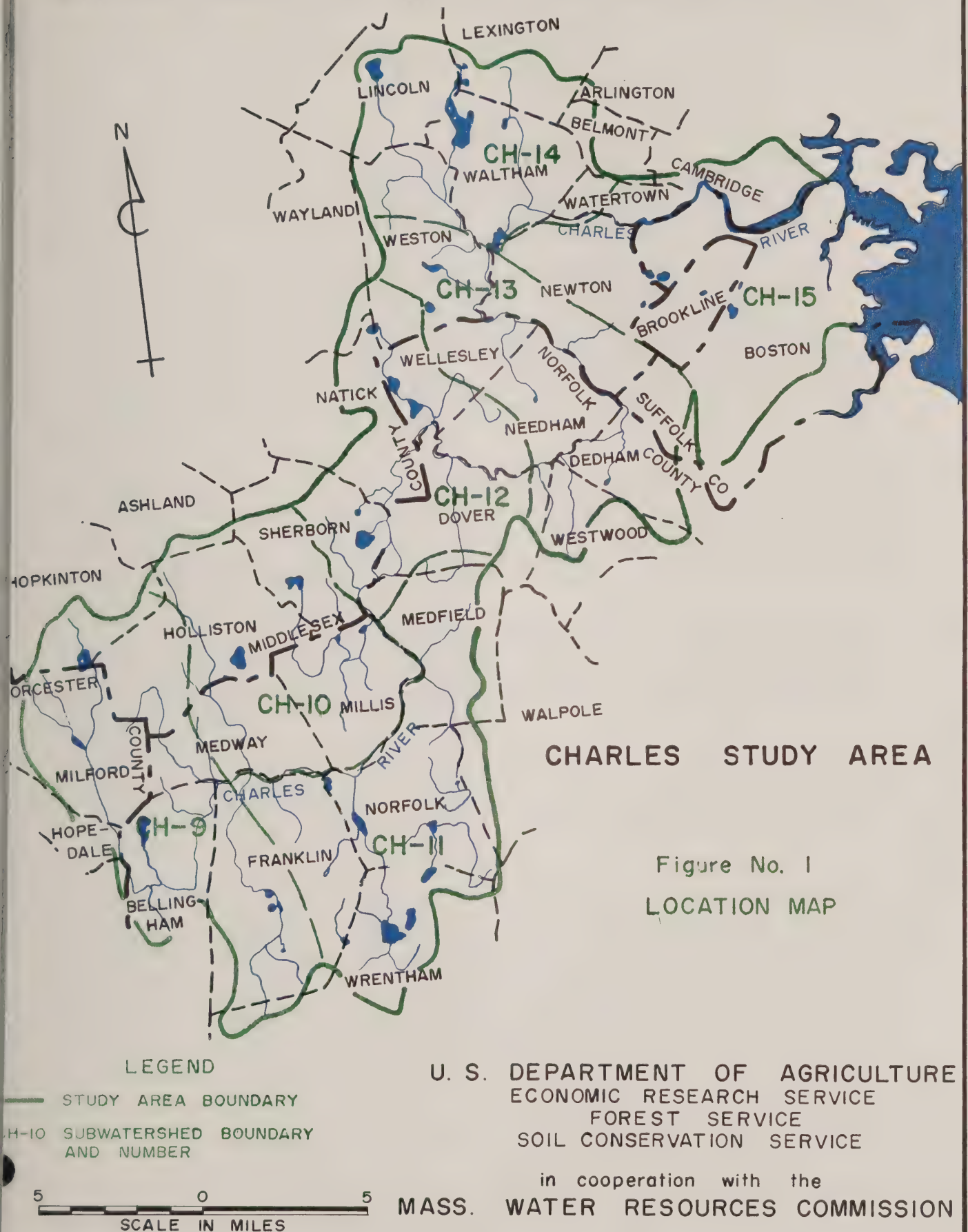
Drainage problems on non-agricultural lands are primarily associated with urban development. These problems should be considered during preparation of urban development proposals.

1.30 Natural Valley Storage

The Corps of Engineers is interested in preserving the major natural valley storage areas, consisting of approximately 8,500 acres, for flood control purposes.

Communities should be interested in such preservation, and not only for the flood control aspect. Wetlands can be of great use to each community as well as being valuable for flood control. The marshes are an asset as an open space greenbelt, for fish and wildlife, for quiet recreation areas, and as open areas affording an aesthetic release for those otherwise bound to the city. Wetlands are also of great value in aiding groundwater recharge and augmenting streamflow during periods of deficient rainfall.

MASSACHUSETTS WATER RESOURCES STUDY



CHAPTER 2 - DESCRIPTION

2.1 General

The Charles Study Area covers the entire watershed draining into the Charles River at Boston Harbor. However, this report is concerned primarily with the upstream portion of that watershed area upstream of the South Natick Dam at Natick, Massachusetts.

As indicated in the Charles River Watershed Plan of Survey, August 30, 1967, the U. S. Department of Agriculture is a member of the Coordinating Committee for this study and will be primarily concerned with that portion upstream of the South Natick Dam (Subwatersheds 9, 10, 11 and 12, Figure 1). This report presents the results of USDA's participation in the study (as well as additional information and data gathered for the Massachusetts Water Resources Study.)

2.2 Physical Data

The Charles River flows generally northeasterly from its headwaters in Hopkinton to Boston Harbor. This watershed includes all or portions of five cities and 30 towns within four counties, including an important and highly developed portion of Metropolitan Boston and less developed, but rapidly growing suburban and rural areas.

The soils on the rolling uplands are generally very stony, well-drained and shallow-to-bedrock. Other areas are stony and sandy with a hardpan layer in the subsoil. Swamps are interspersed throughout the watershed. The soils, because of their texture and permeability, are subject to only minor erosion and sediment.

Topography is generally undulating to rolling and is composed of an uneven mass of bedrock covered with a mantle of till or outwash material deposited by the receding ice sheet or its melt waters. Outwash sands and gravels are abundant. Soils are underlain by complex igneous and metamorphic rocks.

The area has a humid climate and an annual temperature characteristic of the North Temperate Zone. Summers are short and for the most part comparatively cool, with only a few brief periods of hot humid weather. The mean annual temperature is about 50° F. The normal growing season of 176 days extends from about the first of May to mid-October. Mean annual precipitation ranges from 40 to 50 inches. As a rule, precipitation is sufficiently well distributed to prevent serious damage to crops by drought or excessive rainfall.

CHAPTER 3 - LAND USE

3.1 Land and Water Area

The 35 cities and towns located entirely or partially within the Charles Study Area, together with acres and percent of total town area, are listed in Table 3-1. The total land and water area of the Charles Study Area is 307 square miles.

3.2 Present Land Use

For this study, only land use was determined for subwatersheds 9 through 13. Subwatersheds 14 and 15 were considered primarily urban. This land use was determined on the hydrologic watershed boundaries, and not on a total town basis.

The present land uses within the Upper Charles River Watershed, on which land uses were determined, are: forest, 76,980 acres or 56.2 percent; cropland, 2,020 acres or 1.5 percent; pasture, 9,210 acres or 6.7 percent; other, 10,040 acres or 7.3 percent; urban, 36,070 acres or 26.4 percent; and water, 2,480 acres or 1.8 percent.

Of the cropland, about 70 percent is in orchards, nurseries or specialty crops such as truck or berries. The remainder is in row crops. Other land consists of parks, reservations, golf courses or other such areas. Forest is defined as tree-covered land not intensively developed, lands which are at least 10% stocked with forest trees of any size and capable of: producing wood products, exerting an influence on the water regime, providing recreation opportunities, or fish and wildlife habitat (Figure 4). Urban includes those built-up areas where the primary land use is for residential, commercial or industrial.

Present land use in the Upper Charles River watershed, by towns, is shown in Table 3-2 and by watersheds in Table 3-3 for subwatersheds 9 through 13.

3.3 Projected Land Use

Projections of future land use, by towns, were made for 1980, 2000, and 2020 for the following land use categories: cropland, grassland, forest, idle, urban and water. These projections were derived from a detailed land use shift analysis based on 1950 and 1960 aerial photographs for Middlesex, Worcester, and Norfolk counties. Town land uses within counties were assumed to shift in proportion to the parent county shift.

An analysis of these projections reveals that cropland almost disappears as a land use by the year 2020 as does the idle category due to increased urban pressures on the land resource base.

The following table shows the projected change in agricultural and forest land use for 26 towns in the Upper Charles Area vs. 1960 land use:

Year	:	Cropland (Acres)	:	Grassland (Acres)	:	Forest (Acres)	:
1960	:	4688	:	6873	:	79,586	:
1980	:	3112	:	6652	:	76,290	:
2000	:	1165	:	6266	:	71,588	:
2020	:	771	:	5962	:	67,449	:

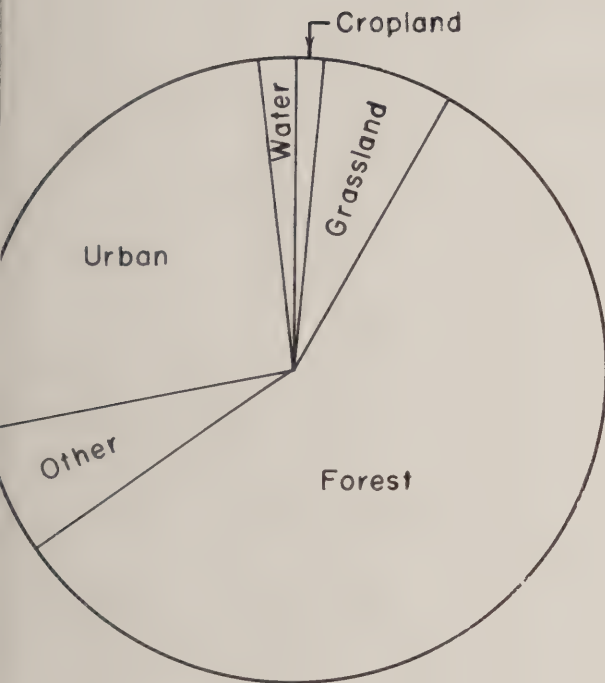
This shows that cropland is projected to decrease by 83.6 percent by 2020, grassland by 13.2 percent and forest by 15.2 percent. The primary crops grown now are specialty crops such as nurseries, berries, orchards, and truck crops. Expanding urban areas, withdrawals of land for highway rights-of-way, and the development of agricultural lands for residential, recreation, home complexes, all are making inroads into the land area available for agriculture. Urban growth will be responsible for the decrease in acreage. Forests of the basin are capable of producing far more wood than they presently are. The productivity of the forest land will depend largely on the caliber of forest management applied on the numerous small tracts of privately-owned forest land. The small size of most holdings results in infrequent return and difficult problems of management.

Projected land use for subwatersheds Nos. 9 through 13 is shown in Table 3-4 for 1980, 2000, and 2020. Figure 2 shows the present land use and the expected proportional changes in these years.

CHARLES STUDY AREA

Figure No 2

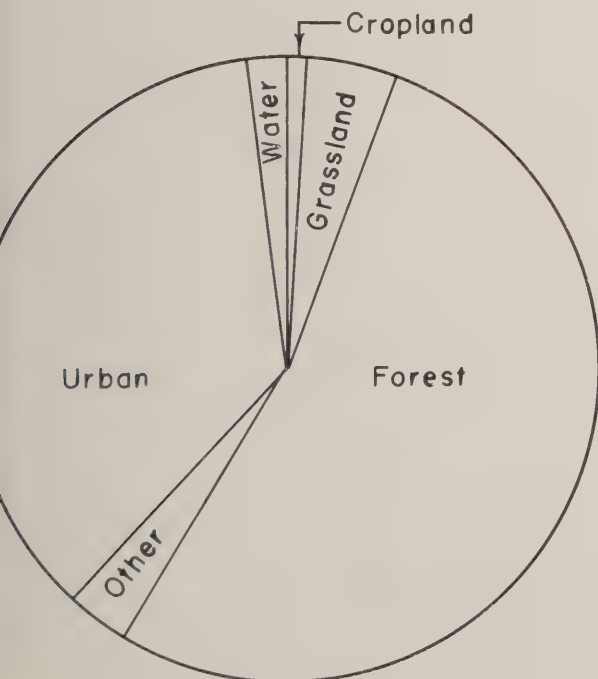
PRESENT AND PROJECTED LAND USE
FOR
SUBWATERSHEDS Nos. 9 Through 13



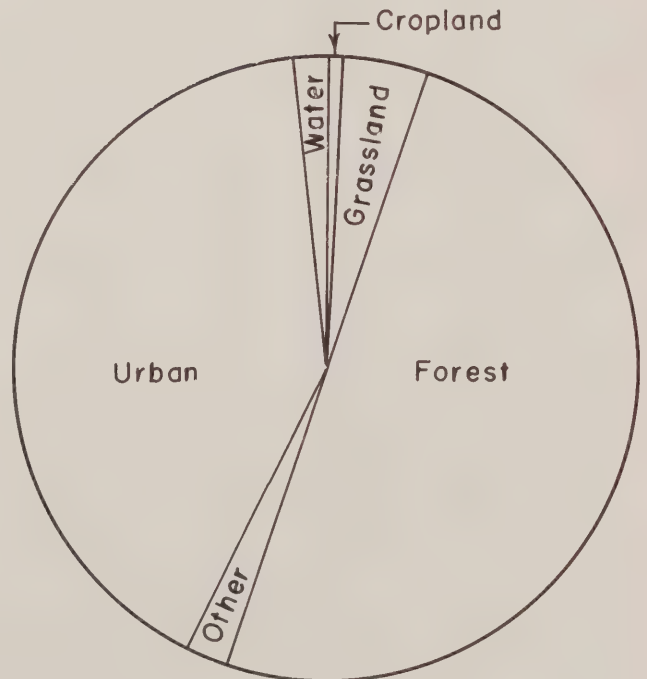
PRESENT As Of 1968



PROJECTED For 1980



PROJECTED For 2000



PROJECTED For 2020

UPPER CHARLES STUDY AREA

Table 3-1
AREA OF TOWNS

TOWN	AREA	
	Acres	% ^{1/}
Arlington	312	9.2
Ashland	381	4.6
Bellingham	6,260	52.3
Belmont	1,359	45.2
BOSTON	21,681	52.0
Brookline	4,332	97.5
CAMBRIDGE	2,944	64.8
Dedham	4,968	73.2
Dover	8,368	86.0
Foxboro	14	0.1
Franklin	15,502	91.1
Holliston	11,862	97.0
Hopedale	614	18.4
Hopkinton	1,924	9.6
Lexington	4,098	38.8
Lincoln	5,763	59.6
Medfield	7,159	77.7
Medway	7,428	100.0
Mendon	219	1.9
Milford	8,212	85.5
Millis	7,808	100.0
Natick	5,411	53.5
Needham	8,100	100.0
NEWTON	11,559	100.0
Norfolk	9,314	99.5
Sherborn	8,201	80.6
SOMERVILLE	321	34.3
Walpole	1,100	11.3
WALTHAM	8,125	100.0
Watertown	2,248	86.8
Wayland	255	2.5
Wellesley	6,082	100.0
Weston	10,015	90.2
Westwood	2,326	32.7
Wrentham	6,248	43.9
Total	203,253	X X

(CITY names in CAPITALS)

^{1/} Percent of total town within Charles River Watershed

11/71

UPPER CHARLES STUDY AREA

Table 3-2

Present Land Use (1968) in
Subwatersheds Nos. 9 through 13

Town	Acres of Present Land Use (1968) - By Subwatersheds ^{5/}					Total ^{1/} Acres	
	Cropland	Pasture	Other	Urban	Forest		Water
Ashland	20	20	20	70	250	*	381
Bellingham	40	360	1,680	780	3,250	160	6,260
Boston ^{2/}	*	*	300	2,050	200	30	2,590
Brookline ^{2/}	*	*	*	250	60	*	309
Dedham	*	70	910	2,390	1,430	170	4,968
Dover	100	640	410	1,130	5,960	120	8,368
Foxboro	*	*	*	*	10	*	14
Franklin	320	1,600	910	2,430	10,070	170	15,502
Holliston	410	570	250	1,970	8,480	180	11,862
Hopedale	*	*	*	200	400	*	614
Hopkinton	10	80	70	50	1,620	90	1,924
Medfield	60	440	790	1,780	4,040	30	7,159
Medway	190	860	130	1,370	4,860	20	7,428
Mendon	10	20	40	20	130	*	219
Milford	20	190	20	2,210	5,610	160	8,212
Millis	40	990	790	1,130	4,800	50	7,803
Natick	330	330	130	1,690	2,790	140	5,411
Needham	110	160	730	5,100	1,870	130	8,100
Newton ^{2/}	10	*	740	3,710	190	90	4,745
Norfolk	120	1,180	430	630	7,090	160	9,614
Sherborn	140	930	300	700	6,200	140	8,401
Walpole	10	190	50	20	1,230	*	1,500
Wayland	*	*	20	80	150	*	255
Wellesley	*	50	740	5,100	560	240	6,682
Weston ^{3/}	10	90	160	740	1,280	20	2,306
Westwood	70	440	420	470	4,450	380	6,248
Wrentham							
Total	2,020	9,210	10,040	36,070	76,980	2,480	136,875

^{1/} Totals do not agree due to rounding off

^{2/} Partial Area

^{3/} Not included

^{4/} * = less than 10 acres

^{5/} Based on hydrologic boundaries

UPPER CHARLES STUDY AREA

Table 3-3

Present Land Use (1968)
By Subwatersheds

TOWN	Acres of Present Land Use (1968) - By Subwatersheds						Total Acres
	Cropland	Pasture	Other	Urban	Forest	Water	
<u>Subwatershed No. 9</u>							
Bellingham	40	360	1,680	780	3,250	160	6,260
Franklin	140	750	800	1,400	5,620	110	8,816
Holliston	20	210	50	240	3,360	20	3,903
Hopedale	*2/	*	*	200	400	*	614
Hopkinton	10	80	70	50	1,550	90	1,851
Medway	10	170	*	230	1,980	*	2,406
Mendon	10	20	40	20	130	*	219
Milford	20	190	20	2,210	5,610	160	8,212
Wrentham	20	40	190	*	360	*	615
Total	270	1,820	2,850	5,130	22,260	540	32,896
<u>Subwatershed No. 10</u>							
Ashland	20	20	20	70	250	*	381
Holliston	390	360	190	1,730	5,130	160	7,959
Hopkinton	*	*	*	*	70	*	73
Medway	180	690	100	1,110	2,860	20	4,947
Millis	40	920	790	1,130	4,770	50	7,701
Sherborn	60	560	120	190	2,470	*	3,409
Total	690	2,550	1,220	4,230	15,550	230	24,470
<u>Subwatershed No. 11</u>							
Dover	*	70	10	*	690	*	777
Foxboro	*	*	*	*	10	*	14
Franklin	190	850	100	1,030	4,450	60	6,686
Medfield	20	400	670	1,740	3,840	30	6,706
Medway	*	*	20	30	20	*	75
Millis	*	70	*	*	30	*	100
Norfolk	120	1,180	430	630	7,090	160	9,614
Walpole	10	190	50	20	1,230	*	1,500
Wrentham	50	410	230	470	4,090	380	5,633
Total	390	3,170	1,510	3,920	21,450	630	31,105

UPPER CHARLES STUDY AREA
(Table 3-3 continued)
Present Land Use (1968)
By Subwatersheds

TOWN	Acres of Present Land Use-By Subwatersheds in 1968 (Cont'd)						Total ^{1/} Acres
	Cropland	Pasture	Other	Urban	Forest	Water	
Subwatershed No. 12							
Dover	100	510	400	1,130	4,390	100	6,630
Medfield	40	40	120	40	210	*	453
Millis	*	*	*	*	*	*	2
Natick	330	330	130	1,690	2,790	140	5,411
Needham	80	130	120	760	1,030	70	2,188
Sherborn	80	370	180	500	3,730	130	4,992
Wayland	*	*	20	80	150	*	255
Wellesley	*	50	530	3,180	430	210	4,401
Weston ^{3/}							
Total	630	1,430	1,500	7,380	12,730	650	24,332
Subwatershed No. 13							
Boston	*	*	300	2,050	200	30	2,590
Brookline	*	*	*	250	60	*	309
Dedham	*	70	910	2,390	1,430	170	4,968
Dover	*	60	*	*	880	20	961
Needham	30	30	620	4,340	840	60	5,912
Newton	10	*	740	3,710	190	90	4,745
Wellesley	*	*	210	1,920	120	30	2,281
Weston ^{3/}							
Westwood	10	90	160	740	1,280	20	2,306
Total	50	250	2,940	15,400	5,000	420	24,072
Total-Upper Charles	2,030	9,220	10,020	36,060	76,990	2,470	136,875

1/ Totals do not agree due to rounding off.

2/ * = less than 10 acres

3/ Not included

4/ Based on hydrologic boundaries

Table 3-4

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UPPER CHARLES STUDY AREA
LAND USE BY TOWNS
WITHIN SUBWATERSHEDS NOS. 9 THROUGH 13
1960, WITH PROJECTIONS FOR 1980, 2000, and 2020

Town and Year	: Crop- : land	: Grass- : land	: Forest	: Idle	: Urban	: Water : Surface : Area
Acres						
Ashland:						
1960.	36	6	251	0	65	0
1980.	33	5	241	0	79	0
2000.	28	4	226	0	100	0
2020.	23	2	211	0	122	0
Bellingham:						
1960.	104	297	3,254	486	778	157
1980.	26	289	3,123	367	1,114	157
2000.	0	276	2,925	185	1,533	157
2020.	0	265	2,751	41	1,862	157
Brookline:						
1960.	0	0	52	0	250	1
1980.	0	0	50	0	252	1
2000.	0	0	48	0	254	1
2020.	0	0	45	0	257	1
Dedham:						
1960.	0	73	1,499	913	2,390	165
1980.	0	68	1,421	842	2,544	165
2000.	0	60	1,299	730	2,786	165
2020.	0	53	1,191	631	3,000	165
Dover:						
1960.	339	402	6,187	397	941	124
1980.	191	387	5,957	186	1,545	124
2000.	0	364	5,607	0	2,295	124
2020.	0	344	5,297	0	2,625	124
Foxborough:						
1960.	0	0	13	0	0	0
1980.	0	0	12	0	1	0
2000.	0	0	11	0	2	0
2020.	0	0	10	0	3	0
Franklin:						
1960.	602	1,367	10,151	1,013	2,374	173
1980.	336	1,330	9,468	630	3,458	458
2000.	0	1,229	8,750	25	5,038	538
2020.	0	1,193	8,207	0	5,642	538

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Town and Year	Crop- land	Grass- land	Forest	Idle	Urban	Water Surface Area
----- Acres -----						
Holliston:						
1960. . . .	633	347	8,793	248	1,974	178
1980. . . .	518	321	8,466	64	2,626	178
2000. . . .	340	279	7,964	0	3,412	178
2020. . . .	180	230	7,425	0	4,085	253
Hopedale:						
1960. . . .	0	5	404	23	197	5
1980. . . .	0	5	404	23	197	5
2000. . . .	0	4	404	22	199	5
2020. . . .	0	3	404	21	201	5
Hopkinton:						
1960. . . .	5	84	1,608	0	48	85
1980. . . .	0	79	1,511	0	114	126
2000. . . .	0	72	1,421	0	211	126
2020. . . .	0	65	1,339	0	300	126
Medfield:						
1960. . . .	227	278	4,154	792	1,784	35
1980. . . .	117	267	3,982	635	2,234	35
2000. . . .	0	250	3,722	397	2,866	35
2020. . . .	0	235	3,497	191	3,312	35
Medway:						
1960. . . .	632	442	4,908	92	1,365	23
1980. . . .	509	429	4,717	23	1,761	23
2000. . . .	319	410	4,421	0	2,289	23
2020. . . .	148	393	4,155	0	2,743	23
Mendon:						
1960. . . .	34	0	125	5	19	3
1980. . . .	33	0	125	5	20	3
2000. . . .	30	0	125	5	23	3
2020. . . .	28	0	125	5	25	3
Milford:						
1960. . . .	37	177	5,613	84	2,208	156
1980. . . .	11	170	5,603	79	2,247	165
2000. . . .	0	159	5,540	70	2,281	225
2020. . . .	0	148	5,538	61	2,303	225
Millis:						
1960. . . .	302	803	4,771	793	1,128	49
1980. . . .	167	790	4,561	601	1,678	49
2000. . . .	0	769	4,242	309	2,477	49
2020. . . .	0	751	3,967	79	3,000	49
Natick:						
1960. . . .	563	97	3,150	127	1,610	104
1980. . . .	518	87	3,022	55	1,865	104
2000. . . .	448	71	2,826	0	2,202	104
2020. . . .	392	60	2,650	0	2,445	104

UPPER CHARLES STUDY AREA

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TABLE 3-4 (Cont'd)

Town and Year	Crop- land	Grass- land	Forest	Idle	Urban	Water Surface Area
Acres						
Needham:						
1960.....	150	143	1,929	734	5,073	131
1980.....	90	137	1,836	649	5,317	131
2000.....	0	128	1,695	520	5,686	131
2020.....	0	121	1,574	410	5,924	131
Newton:						
1960.....	12	0	194	808	3,709	93
1980.....	2	0	160	789	3,772	93
2000.....	0	0	108	760	3,855	93
2020.....	0	0	60	723	3,940	93
Norfolk:						
1960.....	456	865	7,255	434	629	159
1980.....	274	846	6,972	174	1,373	159
2000.....	0	818	6,541	0	2,280	159
2020.....	0	793	6,159	0	2,687	159
Sherborn:						
1960.....	212	856	6,078	239	696	137
1980.....	126	836	5,839	103	1,177	137
2000.....	0	806	5,470	0	1,805	137
2020.....	0	775	5,116	0	2,190	137
Walpole:						
1960.....	45	154	1,047	55	17	0
1980.....	19	151	1,006	18	124	0
2000.....	0	147	945	0	226	0
2020.....	0	143	888	0	287	0
Wayland:						
1960.....	0	0	166	21	82	0
1980.....	0	0	160	18	91	0
2000.....	0	0	150	13	106	0
2020.....	0	0	140	8	121	0
Wellesley:						
1960.....	0	45	559	784	5,100	238
1980.....	0	42	516	744	5,186	238
2000.....	0	37	448	682	5,321	238
2020.....	0	33	388	627	5,440	238
Weston:						
1960.....	23	60	1,412	422	115	143
1980.....	4	56	1,349	386	237	143
2000.....	0	48	1,252	332	400	143
2020.....	0	40	1,165	280	547	143
Westwood:						
1960.....	37	67	1,421	161	739	20
1980.....	9	63	1,368	112	873	20
2000.....	0	58	1,287	38	1,042	20
2020.....	0	53	1,216	0	1,156	20
Wrentham:						
1960.....	239	305	4,592	299	473	383
1980.....	129	294	4,421	142	922	383
2000.....	0	277	4,161	0	1,470	383
2020.....	0	262	3,931	0	1,715	383

4.1 Inventory of Flood Damages

Flood damage surveys were made from the South Natick Dam upstream to the southwesterly watershed boundary. Flood damages in the remainder of the watershed were determined by the Corps of Engineers. These damage surveys included the evaluation of the nature and distribution of land and facilities subject to damage by flood runoff. Possible damages were referenced to the 1955 Hurricane Diane and/or the March 1968 flood. More extensive studies were made on those tributaries where potential reservoir sites were located which could provide protection to downstream areas.

The Upper Charles River, from Echo Lake to the South Natick Dam, was divided into eight damage reaches. Seven of the major tributary streams were considered to be a separate damage reach, for a total of 15 damage reaches. To determine if flood damages could be expected to increase in the future, changes in land use expected to occur by the year 2020 were considered.

After field studies were completed, the feasibility for flood prevention measures on individual tributaries was evaluated. On those tributaries where there were potential sites, the estimated benefits accruing to the installation of reservoirs for flood prevention were compared with the estimated cost for the installation of such measures. Where there were no potential reservoir sites on the individual tributaries, alternative flood prevention measures were considered.

The amounts of estimated floodwater damages, by reaches, are shown in Table 4-1. Location of these reaches are shown on Figure 3.

4.2 Floodwater Damage Prevention and Protection

There are two broad categories of measures which are used for the prevention and/or protection from flood water damages. These are "structural" measures and "non-structural" measures. As implied by the name, structural measures are man-made works of improvement such as floodwater retarding dams, dikes, levees, channel improvements, etc. Non-structural measures include such things as flood plain zoning, flood proofing, conservation land treatment and obstruction removal.

4.21 Structural Measures

Based on a comparison of estimated floodwater damages, with resulting benefits by providing flood protection through structural measures, it was found that there were no justifiable floodwater retarding dams. Also, other types of structural measures, such as channel improvement or diking were found to be unfeasible or impractical.

Therefore, no structural measures are considered for installation for flood protection.

4.22 Non-Structural Measures

4.221 Flood Plain Zoning

Flood plain zoning is placing restrictions on the use or extent of use of lands and areas subject to periodic and seasonal flooding. Section 2 of the Zoning Enabling Act (Chapter 40A of the Massachusetts General Laws) pertains to flood plain zoning and states: "A zoning ordinance or by-law may provide that land deemed subject to seasonal or periodical flooding shall not be used for residence or other purposes in such a manner as to endanger the health or safety of the occupants thereof."

Several of the towns within the Charles River Study Area have some type of flood plain zoning or regulation.

Public Law 90-448, Housing and Urban Development Act of 1968 provides for the Department of Housing and Urban Development to "identify and publish information with respect to all flood plain areas, including coastal areas located in the United States, which have special flood hazards, within five years following the date of the enactment of this Act, and establish flood-risk zones in all such areas, and make estimates with respect to the rates of probable flood-caused loss for the various flood-risk zones for each of these areas, within fifteen years following such date."

The Soil Conservation Service has just completed studies on the Towns of Norfolk, Franklin and Medfield for the Flood Insurance Administration of the U. S. Department of Housing and Urban Development. For Norfolk, maps were prepared showing the 100 and 500-year flood lines along the major streams in the town. Profiles developed for these streams show the 10, 100 and 500-year flood stages. For Franklin and Medfield, maps were prepared showing the approximate 100-year flood line along major streams within each town. This information will be used by USDHUD in their Flood Insurance and Land Management Program under PL-90-448.

In addition to the above special studies, the Soil Conservation Service plans to undertake other flood plain identification studies on selected streams in Massachusetts. Location of studies will be coordinated through the Massachusetts Water Resources Commission.

The U. S. Geological Survey has published hydrological atlases, showing flood-inundation maps for various parts of the United States. Regional flood-frequency reports will cover the coterminous United States, and contain detailed information on stages and discharges not presented in the annual stream flow reports, in addition to descriptive material and pertinent data. Recently, maps for the state were prepared showing apparent flood hazard areas for urban areas with over 40 square mile drainage and agricultural areas with over 100 square mile drainage.

4.222 Land Treatment Practices

Land treatment and conservation practices installed on watershed lands contribute to reducing flood runoffs and thereby reducing flood water damages. These practices tend to retard surface runoff, improve soil infiltration and reduce sediment. Applicable practices include cover crops, conservation crops rotations, reseeding and fertilizing hay and pasture land to provide adequate cover, diversions, open and tile drains, waterways, farm ponds, reforestation, improved forest management, protection, and hydrologic cultural measures, reforestation and improved forest management involving adequate protective measures, and supervised cutting and logging operations.

4.223 Flood Prediction and Warning

Flood damage can also be reduced appreciably by taking evasive or protective action based on flood predictions and warnings. Although the effectiveness of warnings varies greatly depending upon the action time allowed between the predicted flood and its occurrence, studies have shown that, on the average, about ten percent of flood damages could be avoided through proper reaction to flood forecasts. Reaction can take the form of temporary flood proofing of stationary equipment and machines and the evacuation of goods and persons or the building of temporary protective works.

4.2205 Natural Valley Storage

Both the Corps of Engineers and the Soil Conservation Service have identified natural valley storage areas that, if preserved, would serve flood control objectives. These areas consist of about 8,500 acres and 1,170 acres respectively.

Communities should be interested in such preservation, not only for flood protection, but also for the other benefits that wetlands provide. These benefits are discussed in Chapter 10.

A loss of wetland storage will cause increased runoff with a corresponding increase of flood stages. With loss of existing natural storage, future flood stages will be two, three, or four feet higher, from similar storms, than those experienced in 1955 and 1968. This would result in substantially higher flood damages in the future.

UPPER CHARLES STUDY AREA

Table 4-1

ESTIMATED FLOOD WATER DAMAGES 1/

Reach No. <u>2/</u>	Estimated <u>3/</u> Damages (Dollars)	Reach No.	Estimated Damages (Dollars)
I	<u>4/</u>	IX	11,000
II	22,000	X	29,000
III	<u>4/</u>	XI	1,000
IV	8,000	XII	75,000
V	3,000	XIII	7,000
VI	40,000	XIV	2,000
VII	10,000	XV	10,000
VIII	40,000		

1/ Estimated based on occurrence of another storm such as Hurricane Diane (1955)

2/ For location of Reach see Figure 3

3/ Based on 1968 price level

4/ Less than \$1,000

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CHAPTER 5 - EROSION AND SEDIMENT

5.1 Erosion and Sediment Damages

Soils in the Charles River Study Area have a low erodibility factor. The major portion of the rural land is in forest or pasture with very little cropland. Subsequently, erosion and sediment is not considered a major problem. Studies determined that less than 10 pounds of soil/acre/year resulting from sheet erosion reach stream channels from forest lands.

The major source of sediment is the result of residential, highway and industrial construction which are increasing in the watershed. In many instances little or no regard is given for the control of erosion during construction.

Projected changes in watershed conditions should not appreciably increase sediment damages if reasonable precautions are taken.

5.2 Erosion and Sediment Protection5.21 Agricultural and Forest Land Treatment

Conservation land treatment can effectively reduce erosion on agricultural and forest lands and on urban fringe lands. Land treatment practices such as contour farming, cover cropping, terracing, critical area planting, diversions, and pasture and hayland management could be used. Where areas of critical erosion exist the installation of both structural and non-structural measures may be required to control erosion, reduce or eliminate resulting sedimentation, and restore the usefulness of the area. Conservation land treatment practices can be planned and applied by landowners to reduce erosion and sediment from their lands. Technical assistance is available from the local Conservation District and the Department of Natural Resources, Division of Forests and Parks, through their cooperative programs. No specific problem areas or amounts of practices were identified under this study.

5.22 Urban Land Treatment

It has been found that the conservation principles used on agricultural and forest lands can be adapted to urban lands undergoing development.

Provisions should be made for the retention of optimum amounts of vegetative cover for watershed protection on all areas undergoing residential, highway and industrial development and construction. Developers should prepare and follow plans designed to minimize the deterioration of the hydrologic balance and the resulting erosion by maintenance of vegetative cover during development. They should utilize the natural landscape in their planning for environmental purposes. Where necessary, developers and contractors should apply erosion control measures such as temporary debris basins or desilting basins, seeding and mulching exposed areas, temporary diversions, and forest buffer zones during construction. Adequate planning prior to construction and close supervision of construction operations are needed to control this sediment source.

It is recommended that all development plans within urban areas be submitted to the local Planning Board for review. The local Conservation District, with assistance from the Town Conservation Commission, Department of Natural Resources and the Soil Conservation Service, can assist the Planning Board in establishing standards for development that will give proper consideration to:

1. Adequacy of surface water disposal system.
2. Suitability of soils for type of development planned.
3. Need for temporary and/or permanent diversions, desilting or debris basins, mulching and vegetation or other erosion control measures.
4. Maintenance of forest buffer zones and other vegetative cover. The Planning Boards should carefully consider the above items prior to granting approval for the developments. In addition, all proposals should be checked for compliance with the provisions of the Hatch Act (Chapter 131, Section 40) when plans call for altering any streambank, marsh, meadow, or swamp. Broadly construed, the Hatch Act can provide requirements which can be applied toward protecting some lands undergoing development.

6.1 General

Water is a focal point for recreation. Among the active pursuits, swimming is usually the most popular activity for persons on vacations, trips, and outings; with fishing second, and boating third. For persons recreating near home the most popular pursuits are those which can be engaged in for a short period of time. Among the active pursuits are competitive outdoor sports, swimming, and picnicking. Demand for recreation near the home naturally is greater in the heavily populated metropolitan centers.

Development of public recreation areas and facilities should be concentrated in activities which have broad appeal, are in short supply, and are of traditional interest to the State. These are considered to be: swimming, fishing, picnicking, boating, hunting, and camping. Supplementary activities should be provided in conjunction with these.

6.2 Inventory of Resources

The Massachusetts Department of Natural Resources is presently revising and up-dating the 1966 Massachusetts Outdoor Recreation Plan. It is expected that this plan will provide an up-to-date inventory of public and private recreation areas and facilities in Massachusetts.

6.3 Demands for Recreation Activities

For this study, recreational demands were not developed for the Charles Study Area since recreational usages are not confined by hydrological boundaries. Rather, recreational demands were taken from published reports and analyzed to estimate demands for broad areas since the day use area is usually estimated to be that area within two hours travel time.

Based on this analysis, it can be assumed that any recreational opportunities provided in the Charles Study Area will help to meet unsatisfied demands.

Recreation Inventories and Demands are given a more detailed breakdown, description and analysis in Appendix G, Outdoor Recreation and Environmental Considerations, prepared by Commonwealth of Massachusetts, Department of Natural Resources.

6.4 Opportunities for Development

6.4.1 Potential Conservation Pools

Of the five potential sites retained, four sites were identified as having potential for some type of recreational development. Each of these four sites was further evaluated for recreational development. In this evaluation, such items as depth of water, surface area, facilities affected, access to the site and land area suitable for recreational facilities were considered.

Based on this evaluation, these four sites are considered to be practical to install for recreation, with appropriate recreational facilities. These sites can provide opportunities for some type of outdoor recreation activities; such as picnicking, swimming, camping, boating, fishing, or nature study. Table 6-1 shows structure data and Table 6-2 shows the estimated annual user days for the potential uses at the four sites, together with total estimated annual benefits from the recreational benefits. The value of \$1.50 per visit was used to compute the benefits for picnicking, camping and nature study at the various sites. Table 6-3 shows the estimated installation costs and cost allocation. Figure 3 shows location of potential sites, together with selected areas for picnicking and camping.

Picnicking facilities, consisting of about 270 picnic sites, would be provided at four of the impoundments. Approximately 50 campsites would be provided at one impoundment. Swimming beaches, with appropriate facilities, would be available at two impoundments. Boating would be allowed on three of these impoundments. These four sites will provide about 600 surface acres of water, with about 140 acres of additional land for recreational facilities and usage. Recreational facilities that could be installed would provide an estimated 124,500 user days for picnicking; 15,400 user days for camping; 129,150 user days for swimming and 37,100 user days for boating annually. In addition, there would be additional user days from fishing which is discussed under Chapter 7 - "Fish and Wildlife".

The total estimated installation cost, based on 1969 price levels, for the four potential sites for recreation use is \$2,830,000.

These sites are considered to be regional in influence and are to supply regional, rather than local, needs. Therefore, it is recommended that these sites be installed by local interests in cooperation with, and cost-shared by, the Commonwealth of Massachusetts. Following completion, these sites could become State Park areas administered and maintained by the Division of Forests and Parks, Massachusetts Department of Natural Resources.

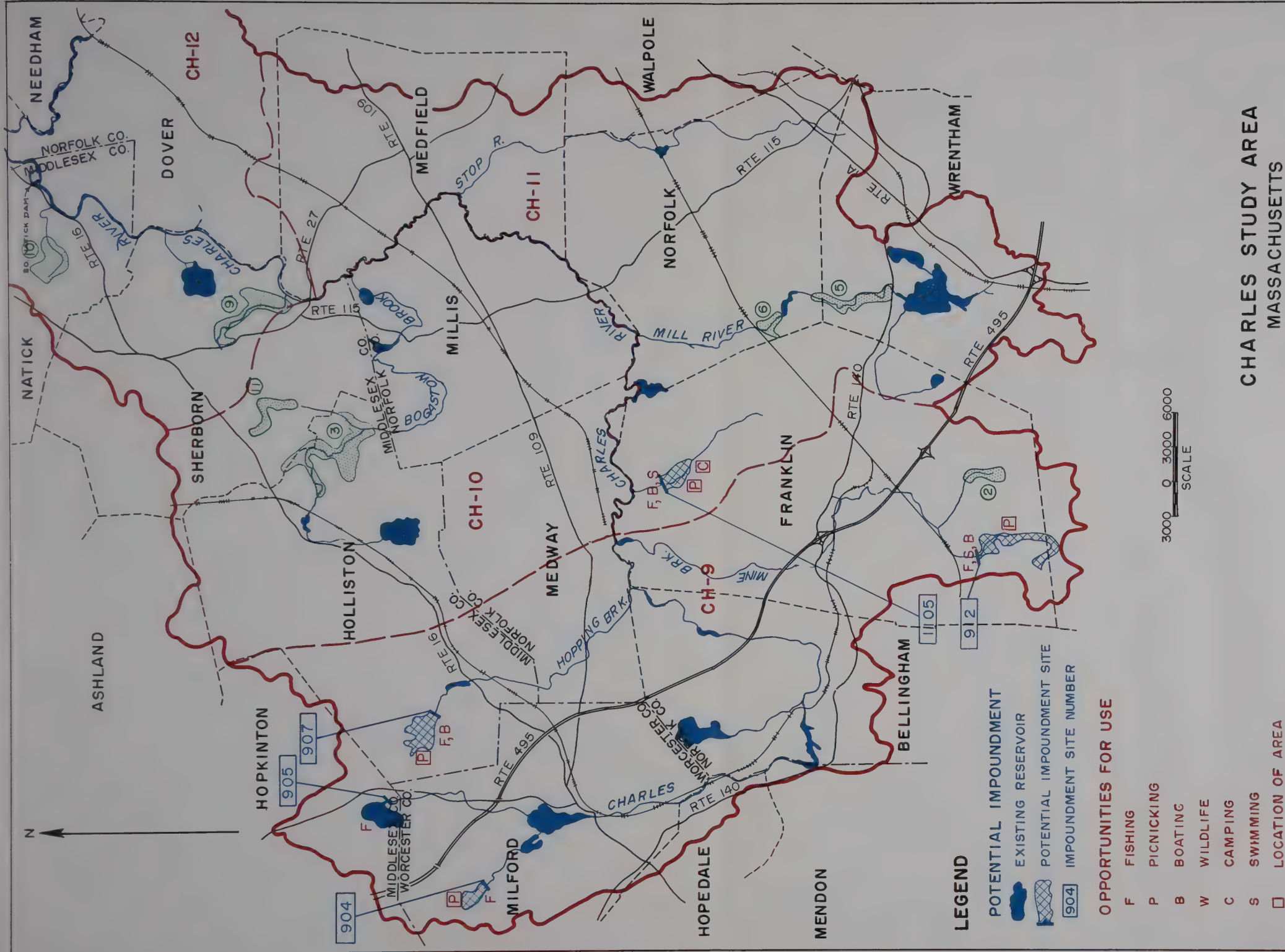
6.42 Local Action Opportunities

Although the above sites will contribute to the unsatisfied demand for outdoor recreation in eastern Massachusetts, there remains recreational needs and more unsatisfied demands on a local basis. Local needs are considered those needs which can best be satisfied on a neighborhood or town basis. Recreational areas to meet these local needs would be installed, administered, and maintained by the town involved.

It is recommended that Conservation Districts and County Foresters give high priority for assistance to towns within the Charles Study Area in Town Natural Resource Programs. This program would identify and help plan and implement local developments to meet local needs. It is further recommended that the Commonwealth, through its various recreation and conservation programs, give high priority to applications for assistance from towns within the Charles Study Area.

6.43 Land Management and Treatment

Development of rural recreation on private land can meet some of the public needs. This can include camp and picnic sites, vacation farms, youth camps, sportsmen clubs, hunting areas, wildlife and nature preserves, hiking and riding trails, flowering vegetation, and scenic vistas. Landowners whose property is suitable for development of a recreational business enterprise or for his personal needs and satisfaction should be encouraged to improve his land for this purpose. Measures that will enhance the scenic beauty and enable opportunities for nature appreciation, sporting pleasure, or other recreation should be recommended through various State and Federal programs. Assistance is provided to private landowners by the Conservation Districts and the Massachusetts Department of Natural Resources.



CHARLES STUDY AREA MASSACHUSETTS

Figure No. 4

OPPORTUNITIES FOR DEVELOPMENT

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

UPPER CHARLES STUDY AREA

Table 6-1
Opportunities for
Development of Potential Reservoirs

Site No.	Town Location	STRUCTURE DATA						Picnicking	Camping	Swimming	Boating	TOTAL <u>3/</u> COST \$1,000
		Permanent Pool					Ave. Depth					
		Elev.	Area	Volume	Max. Depth							
						Ft. MSL						
904	Milford	339	60	350	10	5.8	X					390
905 <u>1/</u>	Milford, Hopkinton	370	165	4470	40	27.1						650
907	Holliston	276	75	1020	29	13.6	X				X	520
912	Franklin, Wrentham	265	285	1730	17	6.1	X			X	X	730
1105	Franklin	197	180	3270	29	18.2	X		X	X	X	1190
5 Sites	TOTALS	-	765	10,840	-	-	4 Sites	1 Site	2 Sites	3 Sites		3480 <u>2/</u>

^{1/} Raise existing water supply reservoir, Echo Lake, for cold water fishing, and increased water supply.

^{2/} Includes cost of associated recreation facilities.

^{3/} Price Base 1969

UPPER CHARLES STUDY AREA

Table 6-2

OPPORTUNITIES FOR RECREATION

Site No.	Beneficial Pool Surface Area (Acres)	Maximum Pool Surface Area (Acres) <u>1/</u>	Estimated Annual User Days <u>2/</u> for					Estimated Annual Benefits (Dollars) <u>3/</u>
			Picnicking	Camping	Swimming <u>4/</u>	Boating <u>4/</u>	Hiking and/or Nature Study	
904	60	-	27,675	-	-	-	15,220	64,310
907	75	-	27,675	-	-	5,840	15,220	64,310
912	285	-	27,675	-	43,050	13,710	15,220	64,310
1105	180	-	41,510	15,400	86,100	17,590	31,300	132,270

1969 Price Base

1/ Surface Area of Low-Flow Augmentation Pool for Water Quality

2/ From SCS evaluation

3/ Based on "Evaluation Standards for Primary Outdoor Recreation Benefits, Ad Hoc Water Resources Council, June 4, 1964."

4/ Not included in Estimated Annual Benefits

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UPPER CHARLES STUDY AREA

Table 6-3

ESTIMATED SITE DEVELOPMENT COST

Site No.	Installation Cost			Total Site Cost (\$1000)	Cost Allocation	
	Dam & Reservoir (\$1000)	Recreation Facilities (\$1000)	Recreation Land (\$1000)		Recreation (\$1000)	Water Supply (\$1000)
904	320	30	40	390	390	-
905	650	-	-	650	-	650 ^{1/}
907	450	30	40	520	520	-
(912)	660	30	40	730	730	-
1105	860	170	160	1190	1190	-

Price Base 1969

^{1/} Assigning all costs to water supply and assuming only incidental costs to cold water fishing.

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UPPER CHARLES STUDY AREA

Table 6-4

ESTIMATED ANNUAL BENEFITS FROM POTENTIAL SITES

Site No.	ESTIMATED ANNUAL BENEFITS			Total Site Benefits ^{1/} (Dollars)
	Recreation (Dollars)	Fish (Dollars)	Wildlife (Dollars)	
904	64,310	2,160	-	66,920
905	-	39,600	-	39,600
907	64,310	3,260	-	67,570
912	64,310	12,390	-	76,700
1105	132,270	7,830	300	140,400
TOTAL	325,200	65,690	300	391,190

^{1/} Based on Evaluation Standards for Primary Outdoor Recreation Benefits, Ad Hoc Water Resources Council, June 1964, and Benefits from Massachusetts Division of Fisheries and Game

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UPPER CHARLES STUDY AREA

Table 6-5

COMPARISON OF BENEFITS AND COSTS FOR POTENTIAL SITES

Site No.	Amortization of Installation Cost @ 5-1/8%	Operation and Maintenance Cost	Total Site Annual Cost	Total Average Annual Benefits	Site Benefits Cost Ratio
904	20,120	8,570	28,690	66,920	2.3
905	- 1/	7,050	7,050	39,600	5.6
907	26,830	9,400	36,230	67,570	1.9
912	37,670	11,100	48,770	76,700	1.6
1105	61,400	21,920	83,320	140,400	1.7
Total	146,020	58,040	204,060	391,190	1.9

1/ All construction costs allocated to water supply and not shown.
The costs and benefits shown are fish and wildlife benefits.

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CHAPTER 7 - FISH AND WILDLIFE

7.1 Problems and Needs

Fishing is one of the more popular activities among persons recreating on vacations, trips, and outings. Total supply of fishing facilities at the present is limited. Hunting is similar to fishing in that game is lacking in the Charles Study area and it can only be supplied on specific types of land. It must be emphasized that long-range waterfowl management and recreational hunting cannot be realized unless large blocks of land at least 500 feet and preferably 1000 feet to the nearest dwelling, is placed under public ownership and with ample accessibility. Because of this, hunting is a difficult activity to accomodate in a metropolitan region such as the Charles Study Area. Lands acquired for this purpose should serve several uses, such as open space, preservation of future sites, preservation of natural wild areas, and other recreational uses.

High population densities can effectively prohibit certain types of fish and wildlife development despite pressing area or demands. The Lower Charles River area is now so completely developed as to deter any significant development for game. In contrast, that part of the Charles Watershed above Newton Lower Falls offers excellent opportunities for both fish and wildlife development and has a recognized waterfowl potential.

There is a notable need and opportunity for the development or improvement of anadromous fisheries in the Charles River and its major tributaries. The current demand for an anadromous fish restoration program in the Northeast, the interstate aspects of such an effort, and the limited number of steams suited to restoration dictate that priority be given to this need on waters with anadromous potential. The proposed Lower Charles Dam, as shown in the Corps of Engineers' report, will assist in the anadromous fisheries restoration for the Charles River.

In addition, there is a need for coldwater and warmwater fisheries in the Charles Study Area. However, most potential sites lend themselves to development for warmwater fisheries since topography limits sites which can impound over 20 percent of the water at depths in excess of 20 feet.

A general need exists for the development of waterfowl hunting and habitat. Needs for fur-animals and non-game mammals parallel those for waterfowl. Economic values and recreational demand for these animals, however, is nowhere as great as those for waterfowl. Therefore, it is believed that the need in most localities is for preservation of existing populations of fur animals and other non-game mammals rather than for additional development.

Non-consumptive uses include bird watching, wildlife photography, nature appreciation and other fish and wildlife oriented recreational uses other than fishing and hunting. The need for these uses is directly proportional to population. Although this need has rarely been given adequate consideration in past planning efforts, it promises to become of increasing importance in the future in such highly developed areas as the Charles Study Area.

7.2 Opportunities for Development

7.21 Potential Reservoir Sites

7.211 Coldwater Fisheries

Only one site was identified as having potential for a coldwater fishery (Site 905-Echo Lake). This site, presently used as a water supply reservoir, would make a satisfactory coldwater or trout fishery if the pool elevation were raised to elevation 370 MSL. Therefore, this site offers an opportunity, by stocking and management, for trout fishing. With public access allowed, this site could provide an estimated 13,200 annual user days of trout fishing. Although Site 905 is presently a municipal water supply reservoir, this offers potential for coldwater fishing since the water supply is not withdrawn from the reservoir, but from the brook downstream and the watershed is fairly isolated. The final decision on use of this reservoir for fishing rests with the local Board of Health and the Public Health Service.

7.212 Warmwater Fisheries

Four sites offer opportunities for management for warmwater fishing. These sites also have potential for other recreational uses such as picnicking, camping, swimming and/or boating. These four sites would provide approximately 600 acres of water surface for fishing for crappies, largemouth bass, sunfish, etc. with an estimated 17,400 annual user days for the sites.

7.213 Trapping and Harvest of Fur-bearers

Sites, installed for recreation or fishing or wildlife, will also provide areas for the trapping of small non-game animals such as raccoon, muskrat, mink, otter, beaver, etc. It is estimated that, for those sites recommended to be installed, there would be 35 user days annually by trappers using the impoundments.

7.214 Non-consumptive Wildlife Uses

All impoundments with public access will offer many other non-consumptive wildlife uses such as bird watching, nature study, wildlife photography, hiking and other fish and wildlife-oriented uses. For example, it is estimated that, for site 1105, there would be 180 user days annually from bird and nature study. In addition, impoundments would provide areas for use for conservation education by school groups, individual or group outings, adult education courses on conservation and many other like uses.

At this time, it is not known or estimated to what extent impoundment areas would be used for these purposes. However, due to the large population within one hour's driving time or less, it is expected that extremely heavy demands will be placed on these areas for all type of non-consumptive uses.

Table 7-1 shows opportunities for site development for fish and wildlife for the five sites, together with the estimated annual user days and estimated benefits.

As shown on the Table, Site 912 was not recommended by the Massachusetts Division of Fisheries and Game for installation due to the present use of Miscoe Brook for trout stream fishing. This site is included in this study because it offers a good opportunity for recreation development. The final decision on whether this site will be installed rests with the local people and the state agencies. Value of the trout stream fishing must be weighed against value of the site for pond fishing, picnicking, swimming and boating.

7.22 Open Space

With the trend toward rapid urbanization of the Upper Charles River Watershed, selected wetland areas with much natural flood water storage capacity and wildlife value should be preserved. Not only is it expected that land values will continue to increase, but the sites can, and probably will be usurped by some type of development such as housing developments and industrial complexes. In addition, these areas will provide significant amounts of natural flood storage that would be lost by development. This loss of natural flood storage will cause higher rates of flood runoff and increased flood peaks downstream. Also, these areas retained in their present state will provide public open space for use and enjoyment.

As shown on Figure 4 (following Table 6-5), 7 areas offer opportunities for conservation and preservation of open space area. Table 7-2 lists these areas, with data on acres needed per area, acres already in public or semi-public ownership, and location. Also, the remaining seven wetland areas would remain as open space for the benefit of surrounding communities and would continue to provide flood protection to downstream communities.

7.23 Land Management and Treatment

Fish and wildlife habitat and production will improve through proper land management. Measures to protect or treat land with various cropping practices, tree and shrub plantings, and forest land improvement cuttings will provide increased flood sources and shelter. Timber and wildlife can be managed to benefit both resources. Technical assistance

is available at local, state and federal offices to provide assistance to private landowners.

7.24 Anadromous Fisheries

The Massachusetts Division of Marine Fisheries, in cooperation with the Division of Fisheries and Game and U. S. Fish and Wildlife Service, has been involved with anadromous fish restoration planning in the Charles River Basin since 1966. At the present time, there is a sizable alewife run up to the Watertown Dam, the Division of Marine Fisheries hopes to reestablish American shad in the near future in the main stem. Preliminary estimates of the shad potential for the river indicate that the main stem could support an adult run of approximately 200,000 fish. This estimate was based on the assumption that all of the main stem up to South Natick could support shad at the rate of 2.3 fish per 100 sq. yd. unit of spawning area. We are presently in the process of bottom typing the main stem to further delineate this preliminary estimate. It now appears that the final estimate of the potential will be in the vicinity of approximately 25 to 50,000 adult fish.

The major obstacles to increasing the existing alewife run and reestablishing shad are, of course, the nine barriers on the main stem. The Division has been involved in planning a fish passage facility with the U. S. Fish and Wildlife Service in the proposed lower Charles River dam, and also are presently negotiating with the MDC to install a fish passage facility in the Watertown dam that would pass both shad and alewives.

The Division is of the opinion that the Charles River can support a substantial sport fishery for shad in the future provided fish passage facilities are constructed on the barriers. It is estimated that approximately 12-to-15% of the run could be harvested in a sport fishery and that a sport fishery in the metropolitan area would be highly desirable, although no attempt has been made to assess the cost benefits of this program. In addition, a shad run in the Charles would increase the non-consumptive recreational benefits in the Basin.

The Division of Marine Fisheries introduced 436,700 shad eggs into the Charles at South Natick Dam in June of 1971. The eggs were transplanted from the Connecticut River.

UPPER CHARLES STUDY AREA

Table 7-1
Opportunities for Development
for
Fish and Wildlife

Site No.	Location		Beneficial Pool Data				Estimated Annual User Days ^{1/}					Total Estimated Benefits ^{1/} (Dollars)
			Surface Area (Acres)	Volume of Storage (Ac.Ft.)	Maximum Depth (Ft.)	Average Depth (Ft.)	Cold-water Fishing	Warm-water Fishing	Waterfowl Hunting	Trap-ping	Bird and Nature Study	
904	Unnamed Trib. of Charles River	Milford	60	350	10	5.8	NE	1,740	NE	NE	NE	2,610
905 ^{3/}	Charles River	Milford	165	4,470	40	27.1	13,200 ^{3/}	NE	NE	NE	NE	39,600
907	Beaver Brook	Hopkinton	75	1,020	29	13.6	NE	2,175	NE	NE	NE	3,260
912 ^{4/}	Miscoe Brook	Franklin Wrentham	285	1,730	17	6.1	NE	8,265	NE	NE	NE	12,390
1105	Shepards Brook	Franklin	180	3,270	29	18.2	NE	5,220	NE	35	180	8,130

1/ Data from Mass. Division of Fisheries and Game

2/ Not evaluated = NE

3/ Using existing Echo Lake water supply reservoir

4/ Mass. Div. of Fisheries & Game does not recommend this site for installation. Benefits based on average use of other sites.

UPPER CHARLES STUDY AREA

Table 7-2

OPPORTUNITIES FOR CONSERVATION AND
PRESERVATION OF OPEN SPACE AREAS

AREA NUMBER	TOTAL OPEN SPACE	PUBLIC OR SEMI-PUBLIC LANDS (Acres)	LOCATION	
			STREAM	TOWN
2	75	0	Dix Brook	Franklin
3	330	5	Bogastow Brook	Holliston, Sherborn
5	210	25	Eagle Brook	Norfolk, Wrentham
6	70	0	Mill River	Norfolk
9	285	100	Unnamed tributary of Charles River	Sherborn
10	100	0	David Brook	Natick
11	80	0	Unnamed tributary of Bogastow Brook	Sherborn
TOTALS	1,150	130		

CHAPTER 8 - WATER SUPPLY AND IRRIGATION

8.1 Rural Domestic and Livestock Water Requirements

8.11 Rural Domestic Water Requirements

It is expected that most domiciles within the Charles Study Area will be serviced through municipal water facilities. In 1963, town or private facilities were serving most of the total population in the Charles Study Area.

8.12 Livestock Water Requirements

Livestock water requirements were based upon the estimated livestock population within the Upper Charles Study Area. The withdrawal per head of livestock in gallons per day for the following animals was estimated to be: Horses and Ponies - 10, Cows - 9, Sheep - 2, and Chickens - 0.1. Therefore, the livestock water requirements would be about 27,000 gallons per day and is expected to be met primarily through existing water sources or municipal water supply facilities.

8.2 Irrigation

8.21 Agricultural Lands

In 1968, there were about 350 acres of irrigated agricultural land in the Charles Study Area or about six percent of the total cropland. About 60 percent of this irrigated land is used for the production of orchards and nurseries.

It is expected that, in future years, most vegetables, fruits, and berries will be irrigated, providing water is available. Factors indicating this are: insurance against drought periods; timely marketing of products to take advantage of highest prices; competition with crop quality requirements obtained by irrigators both in state and elsewhere; higher yields; more efficient plant use of fertilizer; frost protection; and, in the case of cranberries, higher harvest yields.

The availability of water can influence amounts of irrigated land in the future. Present source for cropland is primarily private surface water reservoirs. With the competition from other water users, farmers are expected to rely primarily on private water sources.

8.22 Non-agricultural Lands

Where urban and industrial areas predominate, it is likely that the major water users for irrigation will be for such non-agricultural uses as golf courses, public parks, lawns, etc. Of the 1,440 acres in golf courses in the Charles Study Area, 95 percent or 1,380 acres were irrigated. Private sources of water were used to irrigate 74 percent of the golf courses, with 64 percent from surface water. Only 26 percent of the irrigation water was obtained from public sources.

Although irrigated agricultural lands are expected to increase in Southeastern New England by 1980 and then decline by 2020, non-agricultural uses are expected to increase substantially by 2020.

Adequate water sources for non-agricultural uses will become more important in the future as the use increases.

8.23 Urban Water Supply Needs

To satisfy the demands of an exploding population, municipal water-supply systems in the Charles River Basin must increase their safe yield from the present 270 MGD (million gallons per day) to 480 MGD by the year 1990. Of this 210 MGD increase, only 26 MGD are available from within the Basin. The remaining 184 MGD needed must be imported from elsewhere, principally through expanded MDC (Metropolitan District Commission) facilities.

The potential in-basin supplies are unequally distributed resulting in some communities having more than enough water, and others having no choice, but to seek outside sources to meet their 1990 needs. Sharing of the available local water among certain groups gives many communities the option of either developing an intrabasinal system or joining the MDC system.

All but three of the 35 communities that are fully or partly within the Charles River Watershed fall in the MAPC (Metropolitan Area Planning Council) district, and have been studied in detail as to their present and future water supply needs. Table 8-1 lists the communities in the Basin, their present source(s) of water, and their possible future source(s) of water.

8.4 Opportunities for Development

8.41 Surface Water Potential

Any of the potential sites identified in this study could be used for municipal water supply provided public health standards were met. However, only Site 905 is recommended primarily for water supply. It is recommended that additional future water supply requirements be met through a regional distribution system as outlined in the NEWS Study Reports or through expansion of ground water facilities.

At present, surface water is the chief source of irrigation water. Of the total area irrigated in the Charles Study Area, 73 percent is irrigated through the use of reservoirs. It is recommended that small reservoirs or excavated ponds be constructed adjacent to or nearby the acreages to be irrigated. Size and storage should be based on needs. Technical and consultive assistance for the design of such water storage bodies is available through the Middlesex, Norfolk or Southern Worcester Conservation District Program.

8.42 Ground Water Potential

Present usage of ground water for irrigation is primarily limited to golf courses within the Charles Study Area, or 27% of the total irrigated land. It is expected that future increases of water for irrigation will be provided from ground water sources.

8.43 Urban Water Supply

See main report.

UPPER CHARLES STUDY AREA

Table 8-1

Present and Future Water Supply 1/

Town/City	Present Supply		Basic Options for 1990 Water Supply		
	Local	MDC	Have Sufficient Local Resources	Can join intra-basin system	Must join MDC
Arlington		X			X
Ashland	X				X
Bellingham	X			X	
Belmont		X			X
Boston		X			X
Brookline		X			X
Cambridge	X	X			X
Dedham	X				X
Dover	X			X	
Foxboro	X			Neponset R. Basin Group	
Franklin			X	X	
Holliston	X			X	
Hopedale		Not in MAPC District			
Hopkinton		Not in MAPC District			
Lexington		X			X
Lincoln	X				X
Medfield	X			X	
Medway	X			X	
Mendon		Not in MAPC District			
Millis	X			X	
Natick	X			X	
Needham	X	X			X
Newton		X			X
Norfolk	X			X	
Sherborn	X			X	
Scituate		X			
Walpole	X		X	X	
Waltham		X			
Watertown		X			X
Wayland	X		X	X	
Wellesley	X			X	
Weston	X	X			X
Westwood	X			X	
Wrentham	X			X	

1/ From Division of Water Resources

UPPER CHARLES STUDY AREA

Table 8-2

Components of Proposed MAPC Community Water-Supply Plans 1/
in the Charles River Basin

Group	Subgroup	Towns/Cities
Upper Charles		Bellingham Franklin Holliston Medway Milford Wrentham
Middle Charles	Wayland	Wayland Sudbury (not in Charles R. Basin)
	Wellesley	Dover Millis Natick Sherborn Wellesley Westwood
	Walpole	Medford Norfolk Walpole

UPPER CHARLES STUDY AREA

Table 8-3

Costs of Potential Water-Supply Systems
in the Charles River Basin 1/

Area	Total Cost of community system	Partial Cost of MDC Extension
Upper Charles River Group	\$14,200,000	\$ 8,120,000
Middle Charles River Group	10,200,000	4,009,000 (in addition to \$8,120,000 for Up. Charles R. Group)
Wayland Subgroup	1,370,000	
Wellesley Subgroup	4,550,000	
Walpole Subgroup	4,280,000	
Both Up & Middle Charles River Groups	24,400,000	12,129,000

CHAPTER 9 - DRAINAGE

9.1 Problems and Needs9.11 Agricultural Land

There are approximately 11,200 acres of agricultural land, not including forest land, in the Charles Study Area. Of this amount, only about 380 acres are in some type of cultivated crops. Therefore, needs for drainage works of improvement on agricultural land is considered a minor problem.

9.12 Non-Agricultural Land

Primarily, drainage problems on non-agricultural lands are on those lands undergoing development for residential, commercial or industrial purposes. This includes using wetlands for development purposes and other lands where soils are not suitable for proposed development purposes. To determine drainage needs on these non-agricultural lands, specific sites must be considered individually based on purpose and design of the development.

Generally, all sites which are developed have some type of drainage problem. It is estimated that, for the towns within the Upper Charles Watershed, urban land use will increase over 1960 amounts by about 7,000 acres by 1980; 16,000 acres by 2000; and 22,000 acres by 2020, for a total urban area in 2020 of about 56,000 acres or 41 percent of the total area.

9.2 Opportunities for Development9.21 Agricultural Land

Drainage problems on agricultural lands within the Charles Study Area are considered a minor problem. Any needs associated with drainage works of improvement can be provided under the regular going program of the Conservation Districts.

9.22 Non-Agricultural Lands

Needs for drainage works of improvement associated with non-agricultural lands are primarily on those lands undergoing some type of urban development. The review of development proposals by the Planning Board, with assistance through the Conservation District should identify any problem areas and recommend measures to solve those identified problems. Proposed drainage works should be checked to determine that such works are done in conformance to the "Hatch" Act (Chapter 131, Section 40) or to the Inland Wetlands Act (Chapter 131, Section 40A) when implemented.

A proper review of plans and proposals by specialists could also assure that there would be no detrimental effects to fish, wildlife, natural flood storage, and the ecology of the area where the drainage works were planned.

CHAPTER 10 - WETLANDS

10.1 General

Wetlands are generally considered to be those areas where the water table is near or at the surface of the ground with the soil saturated or flooded most of the time. Soils that can be considered wetlands are those classed as poorly drained or very poorly drained soils.

These wetlands, bypassed to a large extent by developers, may be the areas most valuable natural asset. Surrounded by high-density residential developments, many people have access to them. In addition, these natural wetland areas provide valuable flood water storage, reduce downstream flood peaks and prevent potential flood water damages.

Wetlands occur in the flood plains of the Charles River and tributaries and as pocket or bowl areas in the upper areas. Occasionally, wetland areas are found on upland slopes where the soils produce springs or hill-side seeps.

10.2 Problems and Needs

The basic problem is the preservation of existing wetlands in their natural state. These wetlands are not only valuable for open space areas, but for flood storage, habitat for various kinds of wildlife, and to maintain environmental quality. With the increasing pressure exerted on various kinds of undeveloped lands, greater attention must be given to the protection and preservation of selected wetlands.

Massachusetts wetlands are presently being lost at the rate of one percent a year. If nothing is done to halt this trend, wetlands in the Charles River Valley will disappear at an even greater rate.

Furthermore, if no restrictions are made, these wetlands will be subject to urban expansion and the upstream communities may well become the same as the lower Charles River cities are today, a conglomerate of roads, drives, parking lots, and rooftops.

10.3 Opportunities for Action

The "Inland Wetlands" bill provides a means whereby the Commonwealth can restrict and conserve inland wetland areas. Under the Massachusetts Water Resources Study, information will be provided to the Department of Natural Resources as to wetland areas identified by soil types for selected area. As mentioned before, the poorly drained and very poorly drained soils are considered to be "wetland type" soils. Location of these soil types will be furnished on enlarged USGS topographic base maps (scale of 1-inch = 1,320 feet) with wetland soil boundaries delineated.

The Upper Charles Study Area was selected as one areas on which these wetland soils would be identified on the USGS topographic base maps. Such maps have been prepared for the Towns of Bellingham, Dover, Foxborough, Holliston, Lexington, Needham, Sherborn, Westwood, Hopedale, Medway, Millis, Medfield, Dedham, Natick, Wellesley and Wayland. Copies have been furnished to the Massachusetts Water Resources Commission, the Massachusetts Department of Natural Resources; Division of Conservation Services, and the local Conservation District Office.

To implement the "Wetlands Bill," the Massachusetts Department of Natural Resources, Division of Conservation Services has contracted with a private consultant to identify wetland areas in the Charles and Neponset River Watersheds. These wetland areas are identified on aerial photographs by cover types. Then these areas are checked by field examination. Public hearings are scheduled, on a town-by-town basis, to restrict development of selected wetlands. The wetland soil maps provided by this study will serve as substantiating data in the Division of Conservation Services in restricting development of natural wetlands.

Not only will these wetland identification maps assist state agencies in restriction of wetlands, but will provide information to towns for use in establishing wetland or conservation zoning regulations.

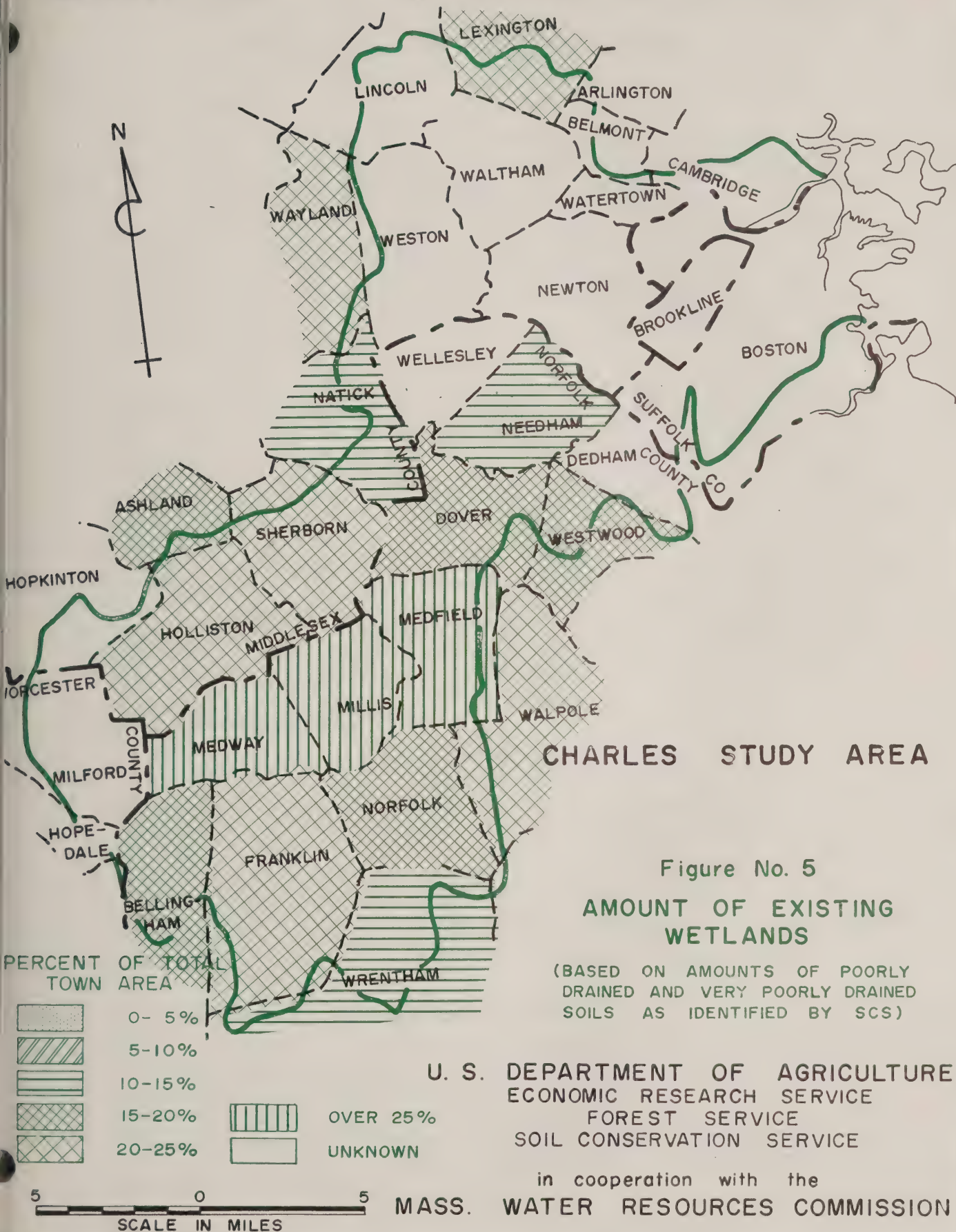
10.32 Town Protection or Restriction

Towns within the Charles Study Area can assist and complement efforts of the Massachusetts Department of Natural Resources in preserving wetland areas. Such methods as flood plain zoning, purchase, conservation easements, or regulation through a permit system, could be used. The Soil Conservation Service, through the local Conservation District, could provide copies of the wetlands identification maps to the above, if requested by Town Officials. It is expected that wetlands identification maps will be prepared for most towns within the Charles River Watershed in the near future.

It is recommended that Towns within the Charles River Area assist the Department of Natural Resources in restricting wetlands. Towns also should coordinate their efforts with the Department to avoid competition for the same areas. In addition, Towns should request Natural Resource Inventories through their local Conservation Districts with particular attention paid to identifying and evaluating wetland areas.

It is further recommended that high priority be given Towns in their plans to acquire existing wetland areas. This could be done through matching grants, incentive funds or technical assistance, such as policies and procedures which could be followed in acquiring these areas.

MASSACHUSETTS WATER RESOURCES STUDY



CHAPTER 11 - WATER QUALITY AND POLLUTION

11.1 General

Several things affect the water quality of a river such as the Charles. Among these are: sewage, both raw and treated effluent; using the river and river banks as a dumping ground; inadequate treatment plants; storm runoff from urban areas; and low-flows. The U. S. Department of Agriculture, in this study, concentrated on determining potentials for upstream impoundments for low-flow augmentations. Other factors affecting water quality and pollution were left to agencies with expertise in those fields, such as Environmental Protection Agency; Metropolitan District Commission; and Massachusetts Division of Water Pollution Control.

From an analysis of the 1967 river survey, the Massachusetts Division of Water Pollution Control determined that new treatment facilities are needed for almost every industrial and domestic discharge to the Upper Charles River; that control of the combined sewer overflows in the lower basin is mandatory; and that a program of river management for pollution control is needed to implement the Water Quality Standards decreed in 1967.

The analysis of the Upper Charles River was accomplished with the aid of computer simulation of the river. The model simulates the dissolved oxygen concentration and BOD, and was verified with the data from the 1967 river survey. The input and output data from the model analysis are available for inspection at the office of the Division of Water Pollution Control in Boston.

11.2 Problems and Needs

11.21 Sewage Treatment - Upper Charles River

The degree of treatment required for existing discharges in the upper valley was calculated by simulating low flow conditions in the river for the year 1980. Because the polluters are already well along in their engineering studies there was little point in evaluating possible regional consolidations for this generation of treatment plants. However, the subsequent analysis for the year 2000 does compare regional versus individual configurations for the many communities involved. For complete text on water quality see Appendix "E."

11.22 Proper Land Use and Treatment

A major source of "pollutants" which lowers water quality is the practice of dumping solid wastes on river banks in the flood plains or establishing "dumps" on areas not suited for such purposes. This occurs along the Charles from both public and private sources. It is recommended that all parties be prevented from dumping any solid materials in flood plain areas, either through prompt enforcement of existing laws or enactment of new laws.

Towns should make full use of soils information when locating new town dumps or relocating existing dumps in flood plain areas. The Town Operational Soil Reports can be used to determine which areas of the town have soils limitations for the use of the area as sanitary land fills; thereby, selection of the best location from a soils standpoint can be made. Considered in these limitations are such things as depth to bedrock, type of soil, location and permeability. It is recognized that location of dumps have political limitations as well. However, each Town must make its own choice between quality environment and public sentiment.

Often in the planning of new residential or other developments, little attention is given to proper land use. In those developments where town sewerage is not available, special attention must be given to "on-lot" sewage disposal systems. In some areas, soils pose severe limitations on the efficiency and functioning of individual septic tank systems. It is recommended that, before approval for unsewered developments are given by Town Boards, the soils conditions at the development be determined. Town Operation Soil Reports can show limitations for septic tanks and forewarn of future problems if unsewered developments are installed in areas with limitations for septic tank systems. For those unsewered developments planned in areas with limitations, it is recommended that Town Boards consider local treatment facilities, furnishing town sewerage or alternate locations for the development.

Restrictions adopted and enforced by the towns will help assure that protective measures are provided in conjunction with developing areas. This will minimize siltation of the waterways. Adequate vegetative cover should be maintained or established, along with other effective protective diversion or infiltration measures as necessary.

Section 5.22 outlines a proposed action program for Erosion and Sediment Protection on Urban Lands undergoing development.

CHAPTER 12 - LAND TREATMENT AND MANAGEMENT

12.1 Present Land Treatment

The following table shows management and treatment measures applied to agricultural and forest land:

Agricultural Land 1/

<u>Practice</u>	<u>Unit</u>	<u>Amount</u>
Open Ditch	Ft.	1425
Tile	Ft.	4500
Farm Ponds	No.	102
Recreation Trails and Walkways	Ft.	4500
Hay and Pasture Seeding	Ac.	2200

Forest Land 1/

	<u>Unit</u>	<u>No.</u>
Tree Planting	Acres	345
Stand conversion	Acres	10
Harvest cutting	Acres	150
Woodland grazing control	Miles	2
Forest management plans	Acres	720

1/ Period 1959-1968

12.2 Problems and Needs

12.21 Agricultural and Forest Land

Problems associated with agricultural and forest land are not considered to be of major importance. The existing agricultural lands should be maintained and improved to provide for diversity of land cover; to provide recreation and fish and wildlife opportunities; and to improve the environmental quality. Forest survey results show that the harvesting of forest products for commercial purposes is rapidly declining. Indications are that within the next 10-15 years commercial activities will be non-existent.

The assessed valuation of forest land is being appreciated by the development of land for housing and recreational purposes, plus increases in the price of land resulting from speculation. In most instances assessed valuation has increased annual property taxes on forest land in excess of annual growth values. Present and future forest landowners are thereby discouraged from practicing desirable forest management.

The current trend in private forest landowner interests is not generally towards the production of timber or associated activities. Most landowners consider personal recreation, residential use, and the satisfaction of owning land the high priority reasons for owning forest land.

12.22 Other Land

The Charles River Watershed is an outstanding example in the region of the way that open space can give distinction and character to an urban area. The basin forms a clear separation between the dense development of downtown Boston and Cambridge, creates scenic areas and exceptional view of city skylines, helps the visitor or resident orient himself, and provides excellent recreational opportunities close to city dwellers. 1/

The population of the Charles River Basin is becoming increasingly aware and involved with problems of land use and development. Programs are needed to provide recreational opportunities, maintain open space, and preserve the amenity values of the landscape. Scenic beauty is an important aspect of the Charles River Basin and is reflected in the great demand for fulfillment of outdoor experiences. Enhancing the scenic beauty of the area is a consideration of the planning agencies.

12.3 Opportunities for Action

12.31 Agricultural Lands

Land treatment practices needed on agricultural and forest land can be applied by individual landowners as the need arises. Good land management and treatment measures protect the water resources and can improve fish and wildlife habitat, recreation pleasures, and the quality of our environment.

1/ Draft - "The Mystic, Charles and Neponset Rivers" - Metropolitan Area Planning Council

Technical assistance should be requested through the local Conservation District, in cooperation with the U. S. Soil Conservation Service and the Massachusetts Department of Natural Resources, Division of Forests and Parks, in cooperation with the U. S. Forest Service.

12.32 Other Lands

Special attention must be given to land treatment practices on lands undergoing urban development. Proper review procedures by specialists in fields related to natural resources will provide guidance to developers in planning and applying proper conservation practices, both during and after development. Technical assistance is available as noted above.

In addition, attention must be given to the maintenance and improvement of the environmental quality of the Charles River Watershed.

12.33 Open Space and Green Belt Areas

The annual loss of open space to urban and related uses is substantial. Once large open spaces are absorbed for other purposes, it is likely that few return to open space. The costs of correcting such situations will be extremely high and in many cases will become impossible.

The Metropolitan Area Planning Council (MAPC), in cooperation with the Metropolitan District Commission, Massachusetts Department of Natural Resources, and the U. S. Department of Housing and Urban Development, has prepared an extensive Open Space and Recreation Plan for the greater portion of the Charles River Watershed. The plan urges action on:

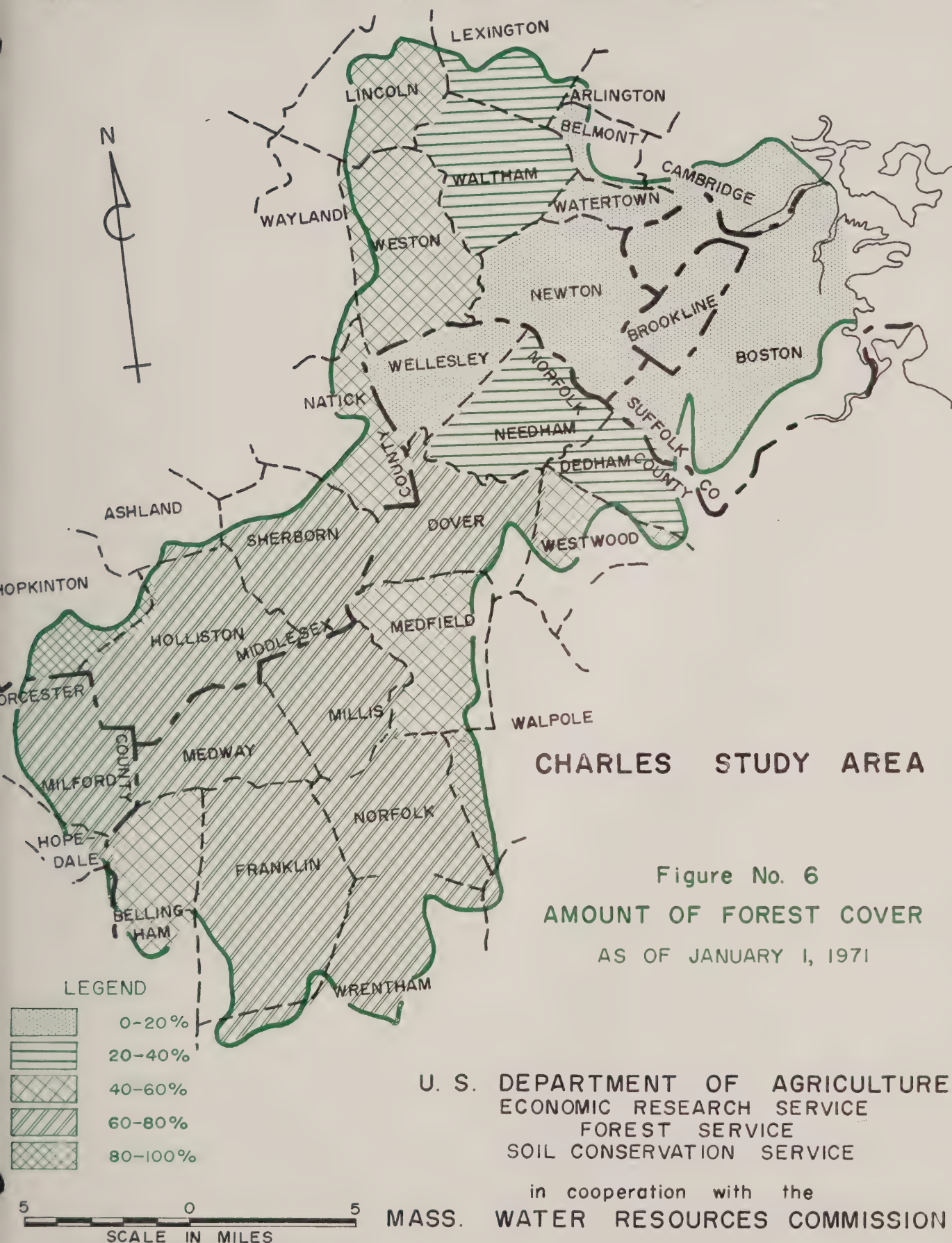
- acquisition of rivers and associated wetlands
- recommends minimum water quality standards
- conservation of extensive wetlands in river flood plains
- park connections between local open space systems and river reservations
- intensive recreational activities at the junctions of rivers and highways and transit lines
- highest priority should be given to the acquisition of natural areas in imminent danger of development
- state and local agencies implementing the plan should take advantage of all available federal assistance programs
- specific acquisition projects

To preserve open spaces and natural areas, it is recommended that a land acquisition program be developed for the Charles Study Area. For the Upper Charles Watershed, it is recommended that 7 conservation areas be acquired as soon as is practical. This would involve the purchase or restriction of approximately 1,200 acres in the Upper Charles Watershed.

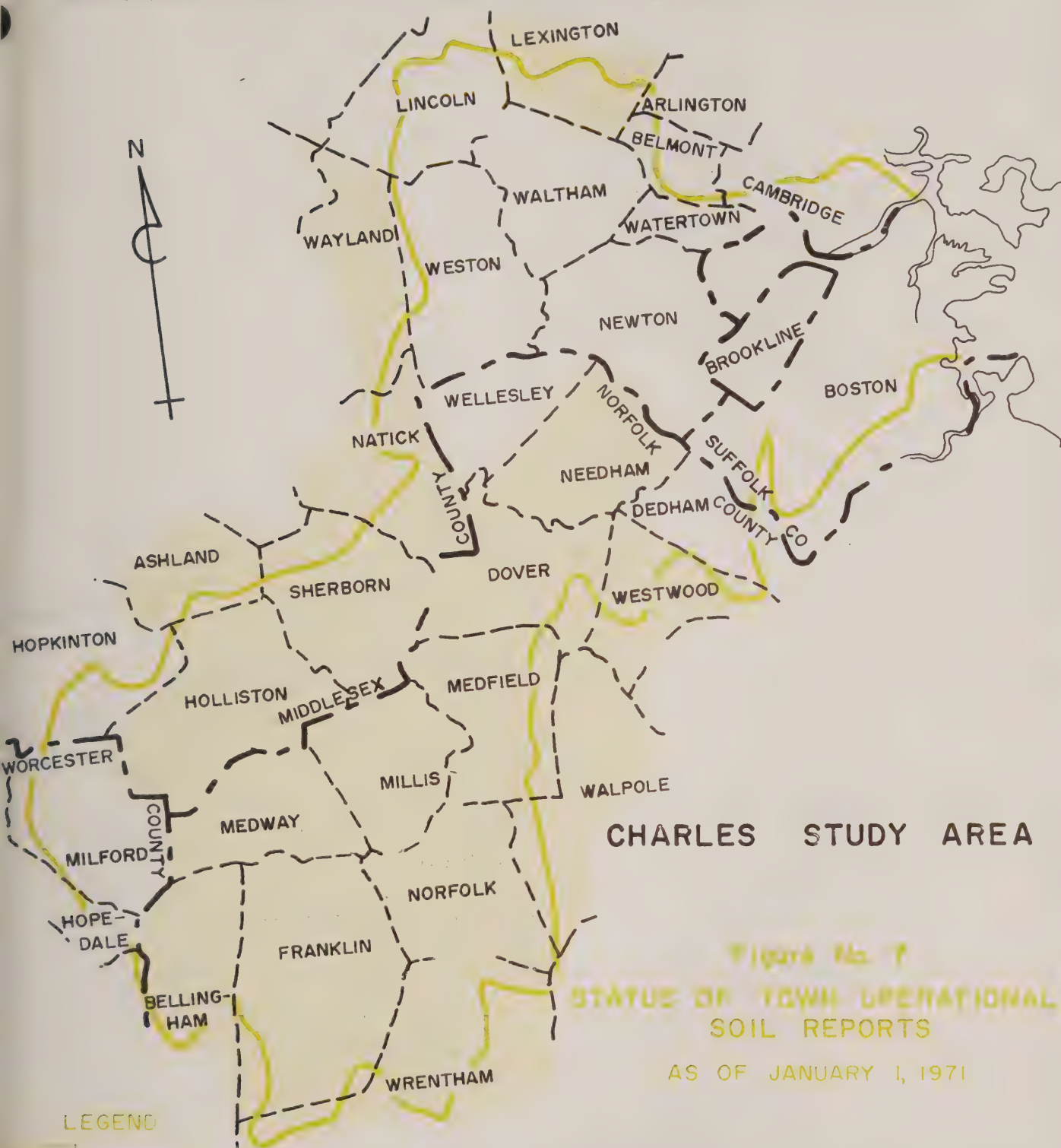
Acquisition of these areas should be coordinated with restrictions placed on inland wetlands under Chapter 131 since most of these sites encompass a wetland area. For location of these areas see Figure 4.

As part of Town Natural Inventories, various locations within Towns were identified as having value and potential for open space, green belt or scenic vistas. These are generally small areas scattered throughout the Town. To maintain or improve the environmental quality of the watershed, it is recommended that high priority be given towns in their efforts to implement their local conservation programs. This could be in the form of such things as: technical assistance in inventorying, planning and installing Natural Resource Plans in each Town; financial cost-sharing assistance or grants to acquire, preserve or develop natural areas; enactment of necessary legislation for authority to carry out various programs to improve the environment; and coordination of all planning actions, including highway locations, sewerage treatment facilities, location of sanitary land fills, flood plain zoning or regulation; and town zoning regulations.

MASSACHUSETTS WATER RESOURCES STUDY

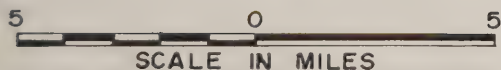


MASSACHUSETTS WATER RESOURCES STUDY



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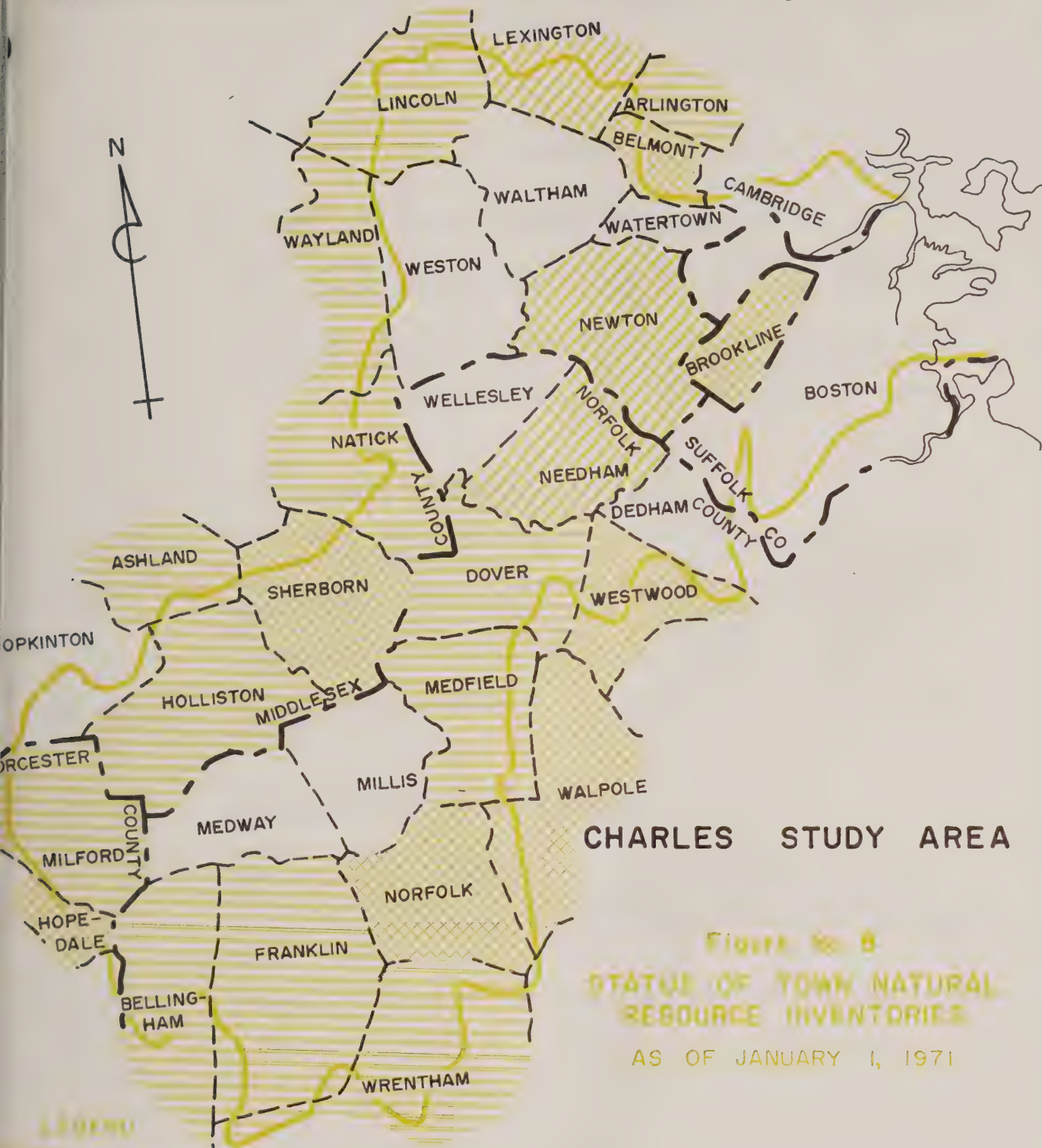
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U. S. DEPARTMENT OF AGRICULTURE
ECONOMIC RESEARCH SERVICE
FOREST SERVICE
SOIL CONSERVATION SERVICE

in cooperation with the
MASS. WATER RESOURCES COMMISSION

MASSACHUSETTS WATER RESOURCES STUDY



CHARLES STUDY AREA

FIGURE 8
STATUS OF TOWN NATURAL
RESOURCE INVENTORIES
AS OF JANUARY 1, 1971

U. S. DEPARTMENT OF AGRICULTURE
ECONOMIC RESEARCH SERVICE
FOREST SERVICE
SOIL CONSERVATION SERVICE

in cooperation with the
MASS. WATER RESOURCES COMMISSION

5 0 5
SCALE IN MILES

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Reports prepared by U. S. Department of Agriculture

USDA Interim Memorandum No. 1 - Water and Related Land Resources of the Upper Charles River Tributaries, September 1968.

This report presents the results of USDA activities in the Charles River Study as of September 1968. An inventory of potential sites, with structural data and maps, is included.

SCS Town Natural Resource Inventories

Towns within the Charles River Study Area which have Town Natural Resource Inventories are: Foxboro, Norfolk, Sherborn, Walpole, and Westwood. Inventories have been started in Hopedale, Needham, and Lexington. Requests have been made, but inventories are not started in Bellingham, Franklin, Lincoln, Milford, Natick, Holliston, Wayland and Wrentham.

Copies of completed reports are on file in the various Town Offices.

SCS Town Operational Soils Reports

Towns within the Charles River Study area which have Town Operational Soils Reports are: Ashland, Bellingham, Dover, Foxboro, Franklin, Holliston, Lexington, Medfield, Medway, Millis, Natick, Needham, Norfolk, Sherborn, Walpole, Wayland, Westwood and Wrentham.

Copies of these reports are on file in the various town offices.

WATER RESOURCE INVESTIGATION

CHARLES RIVER STUDY

APPENDIX G

OUTDOOR RECREATION

AND

ENVIRONMENTAL CONSERVATION

Prepared by

COMMONWEALTH OF MASSACHUSETTS
DEPARTMENT OF NATURAL RESOURCES

Comments by
DEPARTMENT OF THE INTERIOR
Bureau of Outdoor Recreation

DECEMBER 1971

FOREWORD

- The Corps of Engineers and the Massachusetts Department of Natural Resources (DNR) together have a larger action potential for preserving Charles River Open spaces and for potential outdoor recreation opportunities than any other Charles River Study participating agency.
- Most vital to the future welfare of the watershed and region is the guarantee of protection for open areas and it is to this problem the following Appendix addresses itself. The following Department of Natural Resources report was a pilot test of methods and procedures for State-wide outdoor recreation and conservation studies. This Appendix presents the findings and recommendations of the Department of Natural Resources relating to the amount of land to be acquired or protected within its river corridor plan for the Charles River.
- The Department of Natural Resources has been a member of the Charles River Coordinating Committee, and as a result, the plans are fully coordinated. The lands designated to be acquired in the corridor plan do not overlap the natural valley storage areas.
- The Bureau of Outdoor Recreation, Department of the Interior, was furnished a copy of the initial report and their comments are attached.





UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF OUTDOOR RECREATION
FEDERAL BUILDING
1421 CHERRY STREET
PHILADELPHIA, PENNSYLVANIA 19102

7 May 1971 *

In our opinion, the report, Open Space and Recreation Program for Metropolitan Boston, Volume 3, The Mystic, Charles, and Neponset Rivers, prepared cooperatively by the Metropolitan Area Planning Council (MAPC), the Metropolitan District Commission (MDC), and the Department of Natural Resources (DNR) and mentioned on page 60 of the Department of Natural Resources report is essential to any evaluation of recreation-open space potential in the Charles River Watershed area.

Outdoor Recreation and Environmental Conservation in the Charles River Watershed, prepared by the Massachusetts Department of Natural Resources was submitted as input to the State Comprehensive Outdoor Recreation Plan, the evaluation and partial funding of which is the responsibility of this Bureau. We consider this report to be an adequate statement of the importance of the Charles River corridor as open space to serve surrounding metropolitan Boston municipalities which are principally urban or rapidly becoming urbanized. In terms of recreation or open space demand, protection of this important corridor may already be fully justified in existing sources such as the Mystic-Charles-Neponset Study, and previously prepared elements of the Statewide Comprehensive Outdoor Recreation Plan. Supply of open space land in the Boston metropolitan area is low by any calculation, and outdoor recreation demand is great and growing as the population increases and becomes urbanized.

Protection of flood plain areas may be justified on their value as a total environmental resource, even though their value in satisfying some kinds of outdoor recreation demand may appear to be low, and the Department of Natural Resources report discusses this point on pages 48 and 49. Various planning processes, including recreation planning in connection with the State Comprehensive Outdoor Recreation Plan administered by this Bureau, and by the Department of Housing and Urban Development recognize flood plain protection as an important planning principle.

The Charles River Corridor Action Program relies heavily on zoning and other less-than-fee acquisition devices for protection of the river corridor and associated wetlands. Heavy reliance on these techniques for preserving a linear facility such as a river corridor in an area subject to intensive development pressures may be considered somewhat experimental as a preservation concept, even though proposals relying on such techniques have come to light in connection with the trail and rivers programs of this Bureau. Unreliability over time of any single less-than-fee device such as zoning might result in the loss of important sections of the corridor, particularly if funds cannot immediately be made available to acquire any of the lands threatened. We, therefore,

suggest that an overlapping system of protective devices be established for those areas of the corridor in which less-than-fee ownership is involved to provide a measure of safety or "redundancy" against loss of important land. Use of such in-depth protection could involve not only zoning but landowners trusts, covenants, deed restrictions, exchanges of land from land banks and, of course, acquisition of easements. Page 58 of the Department of Natural Resources report also lists other protective measures.

Since the Charles River Corridor under the Action Plan would be administered by a large number of public, semi-public, and private agencies it is suggested that some association of the agencies and groups involved be established to monitor and coordinate policy matters and act out of common interest. A State authority empowered to perform certain functions involving environmental protection might be considered, and such an authority might also be empowered to issue the bonds proposed for the corridor action program on page 59. The Saco River Corridor Study published by the Maine State Park and Recreation Commission in October 1969, contains recommendations for a river corridor authority and this suggestion may be useful for the Charles River.

The outdoor recreation portion of Outdoor Recreation and Environmental Conservation in the Charles River Watershed should receive additional emphasis in indicating a general plan of development in the corridor. The Mystic-Charles-Neponset Study shows proposed intensity of use and schematic location of proposed facilities, and may be adequate for the portions of the corridor shown in that report. Preparation of such a plan would probably require joint participation of the DNR, MAPC and MDC in association with the corridor towns. The recreation activities discussed on pages 56 and 57 appear to be appropriate for consideration in a more specific development plan and are generally the same as those proposed in the Mystic-Charles-Neponset report. We concur with recommendations contained in both reports that protection of the Charles River Corridor would present an excellent opportunity for development of various types of trails. We have advised the Department of Natural Resources of various opportunities for trail development under the National Trails System Act (P.L. 90-543). Page 45 of the Mystic-Charles-Neponset Study recommends that local conservation commissions in conjunction with DNR, MAPC and other interested groups undertake studies of various routes for an interconnected trail system and this might prove to be a workable approach.

The natural valley storage areas in the Charles River Watershed should generally be considered for low intensity uses such as hiking, bicycling, horseback riding, boating and seasonal hunting and fishing. Areas of moderate to high intensity use may also be developed in connection with these areas as outlined in both the DNR corridor report and the Mystic-Charles-Neponset Study. As previously stated, protection of these areas is further justified through their environmental resource value in an urban or rapidly-urbanizing context. Ecology or other environmental considerations, therefore, may dictate the extent to which outdoor recreation development may or should be permitted. We concur with the observation contained on page 48 of the DNR report that urbanization in this area dictates a need to retain as much of these valuable flood plain lands as may be protected in the Charles River study area.

The Soil Conservation Service proposal for impoundments does not appear to be in accord with the other elements within the Charles River Watershed plan, which emphasize natural valley storage and protection of existing resource areas. Justification for these impoundments is based largely on recreation activities and we question the appropriateness of this proposal in a planned setting which favors environmental conservation. Where alternatives exist for natural valley storage, we definitely favor this alternative use.

We would encourage the development of a trails system in the watershed area and we consider the bikeway proposal contained in the interim memo of February 10, 1970 to be recommended specific development of the trails system discussed in the MAPC and DNR reports. Likewise the canoe way proposal contained in the interim memo is a desirable development consistent with the values that are associated with the over-all concept contained in these reports and with which we generally concur. Of course, development of the canoe ways should take account of water quality and its need for improvement as well as possible damage to potentially fragile ecological areas.

In summary, we concur with the over-all objectives of the Charles River Study relating to natural valley storage, and environmental conservation and the proposals to provide generally low intensity recreation development in these areas. Needs and opportunities to develop both high and low intensity recreation facilities consistent with the objectives of the MDC, MAPC, and DNR plans should be explored in connection with a joint recreation plan involving these concerned agencies and the watershed towns.

* These comments were prepared following a review of an April 1970 draft report on Outdoor Recreation and Environmental Conservation in the Charles River Watershed. The reader should note that page number references appearing here may no longer be applicable because of minor format revisions and editorial changes.

CHARLES RIVER STUDY

OUTDOOR RECREATION AND ENVIRONMENTAL CONSERVATION PLAN

COMMONWEALTH OF MASSACHUSETTS • DEPARTMENT OF NATURAL RESOURCES

in cooperation with the

U. S. ARMY CORPS OF ENGINEERS

MAY 1971



FRANCIS W. SARGENT
Governor

ARTHUR W. BROWNELL
Commissioner

APPENDIX G
OUTDOOR RECREATION AND
ENVIRONMENTAL CONSERVATION

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APPENDIX G

OUTDOOR RECREATION AND ENVIRONMENTAL CONSERVATION

Planning Office
Massachusetts Department of Natural Resources

1. REPORT SCOPE AND AUTHORIZATION

This is a draft of a 1970 plan for outdoor recreation and environmental conservation in the Charles River watershed in Massachusetts.

This report and the studies for it are jointly financed by the Commonwealth of Massachusetts and the United States of America, Department of the Interior, Bureau of Outdoor Recreation. This is the first in a series of reports on the Massachusetts 1970 Statewide Outdoor Recreation and Environmental Conservation Plan, Project #25-0046 of the U. S. Land and Water Conservation Fund, which was established in 1964 by Public Law 88-578, as amended.

The Charles River watershed 1970 report is the pilot test of methods and procedures for the whole of the Massachusetts studies. It covers 850,000 population and parts of 35 municipalities in eastern Massachusetts. Much Charles River Study effort went to developing and testing fundamentals for study of the whole of the Commonwealth.

Eastern Massachusetts contains about 66 percent of Massachusetts population, living in 152 of the 351 municipalities of the Commonwealth. Eastern Massachusetts occupies some 2,300 square miles (about 29 percent) of the 8,000 square mile total land and inland waters area of the Commonwealth.



2. PHILOSOPHICAL BASIS OF REPORT

Massachusetts (especially Eastern Massachusetts) is virtually the northeastern terminus of the great U. S. Atlantic coastal urban belt between Portsmouth, Virginia, and Portsmouth, New Hampshire. Washington, Baltimore, Philadelphia, New York, and Boston are the metropolitan anchors of this belt. Here lived some 35.7 million people in 1960 and some 40.0 million in 1970, according to the U. S. Census Bureau, about 20 percent of the national resident population.

The fact of being part of this great United States east coast urbanized area is the philosophic basis of this report, and of all Massachusetts outdoor recreation studies. It constantly underlies the observations and recommendations offered.

The 350 year record of constant growth and interaction of east coast major metropolitan nuclei with one another and with the rest of the nation and the hemisphere, suggest that this great conurbation will continue to exist another fifty to five hundred years, barring international catastrophe. It probably will continue to enlarge a little in territory and more in population, and yet more in intensity of urbanization.

"Non-agricultural ways of life will be followed by more and more people and will occupy much more space than they ever did, and such changes cannot develop without also deeply modifying agricultural life and production." (Megalopolis, Jean Gottman, M. I. T. press, 1966; p. 9)

Accordingly, the goals of the 1970 studies are to assure on-going, humane liveability of the urbanizing environment in Massachusetts, and to assure Massachusetts residents and visitors ample access to a range of outdoor recreation opportunities in Massachusetts in perpetuity.

To accomplish a small part of that large goal, an objective of protecting the entire length of both banks of the Charles River is stated in this report. Policies and procedures to accomplish that objective are indicated in the recommendations section and in the acquisition program section of this report.

Constantly underlying is the thought that continuing urbanization will in time result in buildings or highways or other works of man on every upland, lowland, and wetland space not specifically reserved for outdoor recreation and environmental conservation. It is, therefore, suggested that any and every acre in the Charles River area that can

be preserved or perpetuated for environmental conservation or for outdoor recreation, is ipso facto justified in being so preserved or perpetuated, whether in permanent public control or in private but long-term and effectively "dedicated" control.

This postulate is further discussed in other parts of this report in relation to existing land and water supply, and to present and future recreation demand, outdoor recreation space standards and U. S. participation rates. But at every level of discussion, this report is based on Eastern Massachusetts exposure to three and one-half centuries of unending urbanization.

3. GENERAL NATURAL RESOURCES

The Charles River watershed in eastern Massachusetts drains some 307 square miles to Boston Harbor and Massachusetts Bay. The Charles is the major one of the principal three rivers draining into Boston Harbor: the Charles (80 miles length), the Neponset (28 miles), and the Mystic-Aberjona (12 miles). The Charles River watershed is bordered northerly and northeasterly by the Mystic River watershed; easterly by limited coastal drainage to Boston Harbor; southeasterly by the Neponset River; southerly by the Taunton River (to Mt. Hope Bay); southwesterly by the Blackstone River (to Narragansett Bay); and northwesterly and northerly again by the Sudbury/Assabet/Concord River section and by part of the Shawsheen River section of the Merrimack River watershed, flowing northeasterly into Massachusetts Bay at Newburyport.

An 8-1/2-mile long impoundment above the Charles River Dam (completed in 1910 and located 1.2 miles above the river mouth) is locally known as the "Charles River Basin", and is therefore so named in this report. Consequently, the 307 square mile area topographically draining to the Charles is referred to as the Charles River Watershed, or as the Charles River Valley.

4. GEOLOGY

In common with all of Eastern Massachusetts, the Charles River watershed has several times been heavily glaciated. This has resulted in a shallow, gently rolling valley-plain of low relief, ranging from sea-level to 150 feet elevation in the lower half of the watershed, and to 200 to 250 feet prevailing elevation in much of the upper half of the watershed. The perimeter hills range 200 to 500 feet or more summit elevation above mean sea level.

The older underlying rock formations are deeply covered by earth materials of the glacial period in the lower parts of the watershed and

are less deeply mantled farther up-river. The Boston blue clays, so-called, range down to 200 feet depth or more, and the sands, gravels, clays, and pebble-deposits resulting from glacial action at many other points commonly exceed 100 feet depth. "Although the general features of the topography of this district are determined by the disposition of the hard underlying rocks, the detail of all the surface is chiefly made by the position of the drift or glacial waste left here at the end of the last ice time, but much sorted and re-arranged by water-action." (Nathaniel Southgate Shaler, Memorial History of Boston, Vol. I, p.4; Boston, James R. Osgood and Company, 1880.)

Older harder rocks that show in the watershed are mostly the roots and remains of folds of pre-glacial mountains in eastern Massachusetts that probably were higher then than the alleghanies are now (op. cit. p.3). These older, harder rocks show in hills in Roxbury, Dorchester, Brookline, Waltham, Weston, Newton, Wellesley, and other places, most prominently in Milford. Hemlock Gorge and the former natural falls on the Charles in Newton and Wellesley, also the former falls at South Natick, exhibit the older rocks as do the Rocky Narrows at Sherborn, and other narrows farther up the river.

5. PROFILE

The mantle of glacial drift and the level to gently rolling post-glacial terrain have made the Charles a markedly meandering river. It winds some eighty river miles in bends of two letters "s", angled end to end, while the principal axis of the watershed is about thirty-five miles length between the junction of Milford, Hopedale and Bellingham town boundaries on the Charles, and the river mouth at Boston Inner Harbor.

The Charles River is importantly flat in its natural bottom profile through three quarters of its total length. Between Echo Lake, and Charlestown, the river-bottom falls some 354 feet. Nearly 200 feet of this fall occur in the first quarter of the river-length, between Echo Lake Dam and Medway Dam, 19 river miles(see profile diagram).

The river bottom is nearly level in the middle two quarters of its length: it falls only some 41 feet in 20 river miles between Medway Dam and South Natick Dam, and drops some 18 feet more in 21 river miles between South Natick Dam and Silk Mill Dam at the head of Hemlock Gorge, Newton/Needham.

In the final quarter of its length, the Charles River bottom drops some 86 feet in the final 20 river miles, in three consequential groups of falls.

This recital of the basic geologic and flow-line characteristics of the Charles River outlines its major physical potentials for outdoor recreation. A series of attractive recreation opportunities along the banks, bends, and tributaries of the Charles are indicated by its rather smoothly sloping profile and its meandering pattern, punctuated by falls and (former) rapids, in a mainly non-rocky, gently rolling countryside.

6. PRECIPITATION, CLIMATE AND STORMS, AND FLOWS

The Charles River watershed has a variable climate characterized by frequent and usually short periods of precipitation. The area lies in the path of the "prevailing westerlies" and the cyclonic weather disturbances that cross the United States from the west or southwest. It is also exposed to occasional coastal storms, some of tropical origin, which travel up the Atlantic seaboard and through or near the New England States. In the late summer and autumn months, these storms occasionally attain hurricane intensity.

Rainfall in the Charles River watershed commonly ranges between 40 and 50 inches, average annual cumulative total, distributed rather uniformly throughout the year. In the recent cycle of drought years, 1963-1966, total precipitation fell as low as 35 inches in 1964 and 31 and 1/2 inches in 1883 during 94 years of record at Chestnut Hill. Also at Chestnut Hill, maximums of 63 and 60 inches annual cumulative rainfall were recorded in 1954 and 1888. Thus the maximum for a year may be as much as 28 inches (80 percent) more than the minimum within a five year span.

Annual snowfall (already counted above in annual total rainfall) is in the range of 20-40 inches at Boston Harbor, but 60 inches on the Great Blue Hill, at elevation 640 feet above mean sea level, about 9 miles due south of the Charles River Dam and Science Museum, Boston. Snow cover reaches a maximum depth in early March with the water content often exceeding two inches.

The average of annual temperatures in the Charles River watershed is about 50° Fahrenheit, with a wide yearly range of mean monthly temperatures: 67°-72° F. in July and August, and 25°-29° F. in January and February. Temperature extremes range between occasional highs slightly in excess of 100° F., June-September, and occasional lows below minus 20° F. in winter.

The rapidly moving cyclonic storms or "lows" that enter New England from the west or southwest produce frequent periods of unsettled but not extremely severe weather. The worst storms have often been

those of tropical origin which travel up the Atlantic coast within striking distance of New England. These occur generally during late summer and early autumn. Four notable recent storms in the Charles River watershed occurred in March 1936, July 1938, August 1955, and March 1968. The hurricane "Diane" storm of August 1955 produced floods and damage throughout the Charles and much of southern and eastern New England. The accompanying rains fell on ground saturated one week earlier by rainfall from hurricane "Connie". Precipitation between August 17th - 20th, 1955, ranged between 10 and 13 inches, about 1/4 of the 43 inch annual average rainfall, and about 1/5 of the 1954 maximum of recent years, recorded at Chestnut Hill.

The river is subject to wide variations in water flow volume, with consequent effects on water depth and water qualities for fauna, flora, and outdoor recreation activities. The U. S. Geological Survey maintains and publishes records of three stream gaging stations in the Charles River watershed. One is located near Moody Street in Waltham; the other two are farther upstream. Records at the Moody Street gage indicate a mean flow at this location of 368 cfs for 35 years, 1931-1966; a maximum flow of 2,620 cfs on 22 March 1968; and minimum monthly average flows as low as 15 cfs in summer. These flows reflect the diversion of some Charles River water to the Neponset River by way of Mother Brook in Dedham, about 14 river miles above Moody Street.

Floods on the Charles River may be expected in any season of the year. Early spring rains combined with melting snow resulted in the floods of March 1936 and March 1968. Heavy rains during the summer and autumn months caused flooding in July 1938, September 1954, August 1955, and October 1962. From available information, the greatest such flood prior to 1900 accompanied heavy rain in February 1886. Other noteworthy 19th century floods occurred in 1818 and 1807.

The net meaning of these climatic data is that there are opportunities for four-season outdoor enjoyments in the Charles River watershed, with a panorama of shades of green in spring, and flaming autumn leaf colorings in the birches, maples, and swamp maples relieved by the plainer tones of beech, oak, elm, and catalpa, and rich dark accents of pine, fir, and spruce, year-round.

The enjoyment and safety to be found in outdoor recreation is directly related to the vagaries of weather outlined above. Although it is not yet possible to control the weather elements, the prediction and warning of weather changes can enhance the benefits of the recreational resources. Weather forecasts can be beneficial to the recreationists

for short-range planning; and warnings of severe or threatening conditions contribute to their safety.

The National Weather Service (Formerly Weather Bureau) operates a forecasting office in Boston which serves the Charles River area. In addition to routine weather forecasts, this office has the capability of observing and tracking developing weather situations and almost instant warning of their occurrences. This is done through a competent staff of meteorologists who have continuous access to weather radar observations and also the capability of broadcasting warnings over a dedicated radio frequency (162.40 MHz).

7. STREAM AND POND RESOURCES

Although not a long river, the Charles has numerous tributaries - 78 by one count, nearly one per river mile. Two-thirds or more of the entire watershed, some 208 square miles, is drained to the Charles by 24 streams (and their tributaries) that directly enter the Charles. Eleven of these 24 streams, together drain about half the watershed. They are listed in Table No. 1 in order of size of contributed drainage area.

From Stony Brook, Weston, only occasional overflows now enter the Charles River. The majority of the run-off from Stony, Cherry, and Hobbs Brooks is impounded by the City of Cambridge for its water supply. The Town of Weston also has water supply wells at the confluence of Stony and Cherry Brooks. Thus, the flow from these 23.6 square miles (7.7 percent of the entire Charles watershed) which at one time powered the Roberts Mill, does not enter the Charles.

Each of the Charles' major tributaries appears to have undeveloped potentials for outdoor recreation. Each one not yet buried in conduit either contributes to or detracts from environmental conservation in the communities through which it flows. The Miller's River, Cambridge, and Stony Brook, Roxbury, are each nearly completely buried. The Muddy River, Boston, and Beaver Brook, Waltham, are each buried the last mile of their length. Sawin's Pond and Brook in eastern Watertown are virtually destroyed. Portions of Lemon Brook, Laundry Brook, and Cheesecake Brook in Newton are in culverts or channels.

Listed in Table No. 2 are sixteen natural ponds of 10 acres surface area or more in the Charles River watershed. Fifteen are used for local outdoor recreation. The Charles is the longest river of which the whole length is within Massachusetts.

TABLE NO. 1

TRIBUTARY STREAMS
(Drainage Area)

<u>Stream</u>	<u>Square Miles</u>
Bogastow Brook, Millis	25.5
(Stony Brook, Weston)*	(23.6)
Stop River, Medfield	17.1
Mill River, Norfolk	16.3
Waban (& Fuller) Brook, Wellesley	16.1
Mine Brook, Franklin	15.7
Stony Brook, Roxbury	13.9
Hopping Brook, Medway/Holliston	11.5
Beaver Brook, Waltham/Belmont	11.2
Muddy River, Brookline	7.2
Chicken Brook, Medway/Holliston	<u>7.0</u>
Eleven Major Tributaries	165.1
Huckleberry Brook, Milford	5.0
Shepard Brook, Franklin	5.0
Rock Meadow & Powisset Brooks	5.0
Dover/Westwood/Dedham	
Wigwan & Lowder Brooks, Dedham	5.0
Mill Brook, Medfield/Dover	4.6
Laundry Brook, Newton	4.0
Rosemary & Hurd Brooks, Needham	4.0
Cheesecake Brook, Newton	3.5
Beaver Brook, Bellingham	2.2
Sawmill Brook, Boston/Brookline	2.2
Miller's River, Cambridge/Somerville	<u>2.2</u>
Thirteen Additional Tributaries	42.7

*City of Cambridge Water Supply

TABLE NO. 2
NATURAL PONDS

<u>Pond Name</u>	<u>Approx. Acres</u>	<u>Tributary Stream</u>	<u>Municipality</u>
Turtle Pond	10	Stony Brook	West Roxbury
Jamaica Pond	65	Muddy River	Jamaica Plain
Crystal Lake	40	South Meadow Brook	Newton
Hardy Pond	35	Beaver Brook	Waltham
Sandy Pond*	155	Stony Brook	Lincoln
Nonesuch Pond	30	Bogle Brook	Weston
Morses Pond	110	Waban Brook	Wellesley
Lake Waban	135	Waban Brook	Wellesley
Farm Pond	125	(direct to Charles)	Sherborn
Lake Winthrop	80	Bogastow Brook	Holliston
South End Pond	25	Bogastow Brook	Millis
Mirror Lake	60	Stop River	Wrentham
Lake Archer	80	Mill (Eagle) River	Wrentham
Lake Pearl	80	Mill (Eagle) River	Wrentham
Beaver Pond	35	Mine Brook	Franklin
Beaver Pond	35	Beaver Brook	Bellingham

*Town of Lincoln Municipal Water Supply

MAN-MADE RESOURCES

8. URBANIZATION

Urbanization is the dominating man-made feature in the Charles River watershed in 1970, and has been prominent for 350 years. During the first 45 years of colonization (1630 - 1675) twelve settlements appropriated 75 miles of the 80-mile total length of river.

Now, Interstate expressways virtually frame the Charles River Study area. I-495 traverses the headwaters, crossing the Charles in Milford, also in Bellingham. I-90, the Massachusetts Turnpike traverses the middle and lower Charles through Weston, Newton, and Boston. I-95, Boston-Providence, parallels the southeasterly rim of the watershed, close outside.

State Routes 2, 9, 16, 27, 109, 115, 128, 135, and 140, lace the valley. Soon new Route 209, of expressway calibre and design, may spear the principal length of the valley between Dedham and Milford, paralleling old Route 109. And there is talk of some new "middle circumferential" expressway, paralleling Route 128 some 3 - 5 miles farther out from Boston.

Within this highway (and former railway) network of the Charles are all or parts of 35 municipalities. Five are less than 10 percent by area within the Charles River watershed; 6 are 10 percent - 35 percent in the watershed; and 24 are 40 percent - 100 percent in the watershed.

The residential occupancy of these municipalities varies from densely urban to rather rural in 307 square miles total valley area. Seventy-six square miles in 8 municipalities of the Lower Charles are densely urbanized ranging from 5,700 to 22,800 residents per square mile. Seventy-five square miles in 8 municipalities along Route 128 range from 300 to 3,600 persons per square mile and are continuing to urbanize. The upper 13 towns of the watershed, embracing some 156 square miles in the valley between the headwaters and South Natick Dam, until recently had been mainly rural, ranging from 200 to 2,500 persons per square mile. Since 1960, these towns have been rapidly suburbanizing. See Table No. 3 for county densities.

9. OUTDOOR RECREATION LAND RESOURCES

There were, in 1962, some 140 square miles of forest-lands, grass-lands and orchards in the upper three-quarters of the Charles River watershed. These are the principal upland resource areas available in the valley for meeting future outdoor recreation and environmental conservation needs, apart from existing lowlands, water surfaces and dedicated public open spaces. These forest and other lands are mentioned among "man-made" resources, because they are all that man has so far chosen to leave of fields and woods. Almost every acre of the valley has been worked over by man during preceding centuries of settlement and gradual urbanization. Little of the Charles River Valley surface is in any un-worked, post-glacial state of nature.

Of the 307 square miles in the valley, about 115 square miles were rated "forested" by the U. S. Soil Conservation Service in a September 1968 report from 1962 aerial photographs. These 115 square miles are principally in the middle and upper watershed, as follows:

FOREST ACREAGE* IN CHARLES RIVER WATERSHED

(measured only in watershed portions of municipalities and reported only for selected municipalities, 30% or more in watershed)

Town	Acres*	Town	Acres*
Bellingham	3,255	Millis	4,770
Dedham	1,500	Natick	3,030
Dover	5,995	Needham	1,930
Franklin	10,140	Norfolk	7,280
Holliston	8,795	Sherborn	6,080
Medfield	4,155	Wellesley	560
Medway	4,925	Westwood	1,420
Milford	5,615	Wrentham	4,620

Totals: 74,070 Acres = 115.6 sq. mil

* acres rounded to nearest five or zero

Other forest acreages, measured in small parts of additional Charles River towns, were as follows:

Ashland	250	Newton	195
Boston	200	Walpole	1,045
Hopedale	405	Wayland	165
Hopkinton	1,610	Weston	1,410
Mendon	125		

Totals: 5,405 approx. acres = 8.44 sq. mil.

There are, of course, additional forest acreages in Charles River towns outside the actual watershed boundaries. And within the valley, the SCS reported some 2.3 square miles in orchards or nurseries; also some 14.5 square miles in hay or pasture.

Existing dedicated recreation spaces, some 36.6 square miles of man-made resources, are discussed in paragraph 13, Existing Major Supply,

TABLE NO. 3

MEGALOPOLIS1960 COUNTY AVERAGE PERSONS PER SQUARE MILE

(U. S. Census Bureau Data)

Massachusetts

Essex	1,150
Middlesex	1,500
Norfolk	1,290
Suffolk	14,100

Rhode Island

Bristol	1,490
Providence	1,370

Connecticut

New Haven	1,090
Fairfield	1,040

Pennsylvania

Camden, N.J.	1,770
Delaware, Pa.	3,010
Montgomery	1,040
Philadelphia	15,500

Delaware

Newcastle	700
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District of Columbia

The District 12,500

New York

Bronx	34,700
Kings	37,600
Nassau	4,500
New York	73,900
Queens	16,750
Richmond	3,700
Westchester	1,820

New Jersey

Bergen	3,330
Essex	7,100
Hudson	13,000
Mercer	1,170
Middlesex	1,390
Morris	559
Passaic	2,100
Union	4,890

Maryland

Baltimore	
County	820
Baltimore	
City	12,500
(Combined)	2,130

Boston and the Lower Charles are in much the same density range as Washington, D. C., Baltimore, Maryland, Philadelphia Pennsylvania and Newark, New Jersey. New York City (except Queens County) is 2-1/2 to 5 times the population density of Suffolk County.

10. OUTDOOR RECREATION WATER RESOURCES

Of the 35 watershed municipalities, 12 do not touch the Charles, and 23 front on or embrace the river. For three-quarters of its total length, the banks of Charles River are in separate municipalities, as well as traversing parts of four counties. Both banks of the river are in the same township in only a few instances, totaling 23-1/2 river miles, tabulated below. The division among cities, towns, and counties, and the resulting divided citizen responsibility, may have contributed to Charles River bank deterioration and neglect.

THE CHARLES AS MUNICIPAL BOUNDARY

<u>Non-river Municipalities</u>	<u>Same Town Both Banks</u>		<u>Diff. Town Each Bank</u>	
Arlington*	Bellingham	5 1/2 mi.	Bellingham	3 1/2 mi.
Ashland*	Dedham	4 mi.	Boston	10 1/2 mi.
Belmont	Hopkinton+	2 mi.	Cambridge	6 mi.
Brookline	Medway	1 mi.	Dedham	4 1/2 mi.
Foxborough*	Milford	4 1/2 mi.	Dover	10 mi.
Holliston	Natick	2 1/2 mi.	Franklin	4 1/2 mi.
Lexington	Waltham	3 mi.	Hopedale	2 mi.
Lincoln	Watertown	1/2 mi.	Medfield	9 mi.
Somerville		23 1/2 mi.	Medway	5 mi.
Walpole+			Mendon*	2 mi.
Wayland*			Milford	1 mi.
Wrentham			Millis	10 mi.
			Needham	12 mi.
			Newton	11 1/2 mi.
			Norfolk	2 1/2 mi.
			Sherborn	4 mi.
			Watertown	4 mi.
			Wellesley	4 1/2 mi.
			Weston	3 mi.
			Westwood	0.1 mi.
				109 1/2 mi.

+Only 10 percent in watershed (2)

*Less than 10 percent in watershed (5)

For too long this river-bank division has made the Charles "nobody's" river for outdoor recreation and environmental conservation.

Under-utilized outdoor recreation and community beautification opportunities exist at each of the twenty dams now impounding the Charles. At or near each dam there are opportunities for recreational enlargement

and for environmental conservation without "manicuring" the banks. Among impoundments noted in the reports of the U. S. Army Engineers, those of largest potential for recreation and beautification in the 1970's appear to be the following:

THE CHARLES RIVER IMPOUNDMENTS

<u>Chas. Riv. Mi.</u>	<u>Dam</u>	<u>Crest Elev.*</u>	<u>Approx Pool Length</u>
1.2	Chas. Riv. Dam	10.4(lower lock-gate)	8.5 mi
9.6	Watertown	8.6	0.75
12.6	Waltham	35.5	5.4
20.	Silk Mill	84.0	10.5
34.	Chas Riv Village	101.3	6.0
41.	South Natick	110.5	4.0
58.	Populatic Pond	a natural embayment	
60.	Medway	159.3	1.5
66.	N. Bellingham	200.9	2.0
70.	Box Pond	221.8	1.5
80.	Echo Lake	353.6	0.8

*Reported elevation in feet above mean sea level, USGS.

These impoundments, and others intervening, have established a landscape necklace of pools along the whole length of the river, and make possible the canoeing of the lower sixty miles of the Charles much of the year, (see Appalachian Mountain Club canoe book), but more especially in spring at high water.

Charles River water volume varies widely: in dry months and years, as little as 1 to 15 cubic feet per second flow through the Waltham USGS gaging station; and as high as 2,600 cubic feet per second has been recorded at Waltham in spring freshet or occasional hurricane storms.

Additional water-surface areas of consequence in the Charles River Valley are a half dozen man-made water supply reservoirs, not currently available for recreation as follows:

Chestnut Hill	Boston
Fisher Hill	Brookline
Hobbs Brook Basin	mainly Waltham
Stony Brook Basin	Weston/Waltham
Norumbega Reservoir	Weston
Weston Reservoir	Weston

11. HISTORIC AND CULTURAL RESOURCES

The Charles River Valley, Massachusetts, is an important locus in the early beginnings of corporate white settlement along the Atlantic coast of North America. To the Charles in the autumn of 1630 came most of the Massachusetts Bay Company that had landed in June that year at Salem, Massachusetts, nearly 1,000 in number. They had sailed together from England in March 1630 in seventeen ships, bringing families, family possessions, trades, tools, animals, seeds, and their crown charter. They were the largest in numbers, most diverse in skills, best equipped and best organized colonizing group to arrive on the North American Atlantic coast before 1650. They were the only duly chartered group to arrive in their entirety, fully self-governing under the terms of their charter.

The Plymouth Colony neighbors of 1620 landing were permittees of the London-governed Virginia Company, and had intended landing some hundreds of miles farther to the south within the broad territories of that company.

The Massachusetts Bay Company grant, being later, was territorially more confined: three miles south of the Charles River on the south, and three miles north of the Merrimack River on the north, and, in the vague knowledge of North America of that day, from the Atlantic Ocean on the east to the Pacific on the west.

The Charles River was so named for the royal prince and patron of the 1614 New England exploration voyage by Captain John Smith. Within the Charles River Valley were most of the early, inland settlements of the Massachusetts Bay Company, also their seat of government and major center of business. As a result, within and on the edges of the Charles River watershed there are a large number of sites and buildings and collections of records and relics attaching to the early beginnings here of self-government and of the problems and growth toward federal union of the thirteen American colonies.

More than a hundred such sites quickly come to mind in the watershed portions of Boston, Brookline, Cambridge, Newton, Waltham, and Watertown. A very few of the most obvious clusters of sites are Breed's Hill, Charlestown; Beacon Hill, Boston; North End, Boston; Back Bay, Boston; East Cambridge; Old Cambridge (Harvard Square, Mt. Auburn, Tory Row, etc.); Brookline; Chestnut Hill; and river-side portions of each of the Charles River towns, especially the former Indian reservation at South Natick. Sample houses include the Paul

Revere house, Boston; the Frost-Cooper-Austin house, the Apthorp, Vassall, Longfellow and James Russell Lowell houses in Cambridge; the Abraham Browne house in Watertown; the Governor Gore house and grounds on the Watertown/Waltham boundary; the Vale in Waltham; the Jackson Homestead in Newton; the Fairbanks house and other houses in Dedham; also early houses in Needham, Dover, Medfield and Sherborn.

The springs and hillside headwaters of the Charles River in Hopkinton are themselves of historic interest. They were at one time part of a very large land possession by trustees under the will of Edward Hopkins, an early Governor of Connecticut. The trustees, mainly the President and Fellows of Harvard College, in desperation tried to start in Hopkinton an early proprietary "new community" with ground rents to the trustees. And, to aid their venture in support of higher education (pursuant to Hopkins' will), they persuaded the Colonial government to join unto the Hopkins' holdings, all or most of large Massachusetts Province Lands nearby, and to set the whole off as a new municipality, Hopkinton, so established in 1715.

In addition to specifically colonial and revolutionary historic sites and associations of national importance, there are current day educational, cultural, and technical institutions and facilities of national, and indeed of world importance in the Charles River Valley. Among a larger number, there may be named here only a few of the most prominent: the universities of Harvard, M. I. T., Boston, and Brandeis, for example, and of women's colleges: Radcliffe, Simmons, Wellesley, and Regis. Also there is the pioneering Perkins Institute for the Blind at Watertown, and its earlier associations with Dr. Samuel Gridley Howe and his wife Julia Ward Howe. In the fields of health, education and welfare, there may be mentioned the Harvard Medical School, the Massachusetts General Hospital (first documented use of ether in surgery), the Lahey Clinic, Beth Israel Hospital, the two special "Brigham" hospitals, the New England Deaconess Hospital and the former New England Hospital for Women and Children, all within the Charles, and indeed, the Lower Charles study area. There are also, in the Charles River Valley, the Boston Athenaeum, the Boston Fine Arts Museum, the Boston Science Museum, the Boston Public Library, the New England Medical (reference) Library, the New England Theological Library, and many other special educational, cultural, and historical institutions, for example, the New England Historic Genealogical Society, and the Society for the Preservation of New England Antiquities.

Individual buildings of architectural merit and historic importance abound throughout the Charles River watershed; it would take several volumes to list and describe them in worthy detail.

Some of the finest aesthetic elements of Charles River urbanization, however, are its village greens and city and town commons, often flanked by notable buildings. And the final element of urbanization to be mentioned here is the 750-acre Charles River former tidal flats filling and development, the Back Bay district, which itself has been described as one of the great urban works of art in North America, and a chief ornament of the city of Boston.

12. PRE-HISTORIC

Special and fragile resources along the Charles are the pre-Columbian archeological sites of aboriginal settlement, which have been indexed for the Corps of Engineers by a doctoral thesis student under the auspices of the Peabody Museum, Harvard University. The sad facts of recent years are that residential subdivision, also sand and gravel quarrying, and finally, un-tutored local citizen digging, have seriously affected many of these sites. To publicly identify them might only precipitate complete destruction.

OUTDOOR RECREATION SUPPLY

13. EXISTING MAJOR SUPPLY

In 1970 eleven hundred existing dedicated outdoor recreation sites in the Charles River watershed occupied more than 26,000 acres and afforded residents and visitors a variety of outdoor recreation opportunities. Except for the Minute Man National Historic Park project, the acreages are roughly divided into three parts among State (and metropolitan district), municipal and private administration.

CHARLES RIVER EXISTING OUTDOOR RECREATION SUPPLY 1970

<u>Sites</u>	<u>Administration</u>	<u>Approx Acres</u>
5	Federal (mainly Minuteman National Park)	680
12	State Forest & Park Lands	5,000
40	Metropolitan District Commission Parks	3,090
947	Municipal Park & Recreation Areas	10,100
<u>126</u>	<u>Private, Dedicated, Recreation Areas</u>	<u>7,480</u>
1,130		26,350
	(say 41.0 square miles)	

Some 200 or more additional - mainly institutional, religious or educational - sites in the watershed embraced additional 12,000 acres, in categories as follows:

State (mainly institution) lands	4,225
Municipal water lands	1,040
Municipal school sites (and parking)	1,655
Municipal unclassified lands (incl.dumps)	1,615
Private religious or educational	<u>3,665</u>
	12,200 acres
(say 18.8 square miles)	

The foregoing summarizes in rounded numbers all existing "dedicated" outdoor recreation sites and other sites deemed related to outdoor recreation in those 29 municipalities 10 percent or more by gross area within the Charles River watershed. These sites and acreages are somewhere within the respective municipalities, but not all sites are within the watershed. Accordingly, in the foregoing figures are some 3,100 acres of State and Metropolitan District lands in Hopkinton and Wrentham that are near but not within the watershed boundary. Included also are 930 acres of play-space, being 1/3 of all major school site acres. This fraction is meant to cover the formal and informal play-able portions of total school acreage. The other 2/3, representing the built-up portions of the school sites are in the school building lands entry at the top of this page.

The geographic distribution by towns of the foregoing 26,000 recreation acres and the 12,000 institutional acres is set forth in two accompanying pages of tables in 14 identical column headings. Table No. 4 shows acreage and Table No. 5 the numbers of sites, per public or semi-public ownership category.

Within the 26,000 acres and 1,100 outdoor recreation sites, there are opportunities for participation sports and for less active or less organized recreation as follows:

VARIETIES OF OUTDOOR RECREATION SITES IN THE CHARLES

Water Related

State and MDC Swimming Pools
Municipal (including High School) Swimming Pools
College and University Swimming Pools
Private Club (incl. Country Club) Swimming Pools
Motel Swimming Pools

VARIETIES OF OUTDOOR RECREATION SITES IN THE CHARLES
(Cont'd)

Water Related
(Contd)

Family Back Yard Swimming Pools
Outdoor State, MDC and Municipal Fresh-water
Swimming places
Charles River Power Boat Mooring Areas
Charles River Sailing Dinghy Mooring Areas
Charles River 8-oar and lesser rowing-shell stations

Land Related

State and MDC Skating Rinks (machine-made ice)
Private Club and Fee-pay Skating Rinks (machine made ice)
School, College and University Skating Rinks (machine-made ice)
MDC and other Skiing Areas
State and MDC Playing fields and Stadiums
Municipal High School and Junior High School Playfields
Private Preparatory School Playing fields
Private College and University Playfields and Stands
Elementary School Age Playgrounds - MDC
Elementary School Age Playgrounds - Municipal
Elementary School Age Playgrounds - Private
State and MDC Golf Courses and Tennis Court Areas
Municipal Golf Courses and Tennis Court Areas
Private Golf Courses and Tennis Court Areas
Youth (summer) Camping Grounds - Private
Youth (summer) Camping Grounds - State or MDC
Family Camping Grounds, Private and Public
Private Fishing and Small Game Hunting Clubs
Public, Stocked Fishing and Inland Game Areas

Quiet Recreation

National Register Natural Landmarks
National Parks and Reservations
State and MDC Parks and Greens
Municipal Parks, Commons and Greens
Private dedicated, outdoor reservations
State and MDC Forest Reservations
City and Town Forests

VARIETIES OF OUTDOOR RECREATION SITES IN THE CHARLES (Contd)

Quiet Recreation (Contd)

Municipal Conservation Commission Lands
Municipal Water-lands and Water Bodies
MDC Aqueducts and Reservoirs
Major Natural Ponds
Major Wetlands along the Charles and certain tributaries

Cultural

Public Gardens
Zoological Garden
Aquarium
Outdoor Music Concern place
Other Outdoor Amphitheater
Star Observatory, outdoor
Indoor Planetarium

Historic

National Register Historic Sites
Massachusetts Register Historic Sites
Locally identified historic sites (residential, industrial,
public and other)

In the Charles River valley are some of each of the above listed eleven outdoor recreation site types. Also in the Charles are major in-door urban recreation and entertainment facilities that draw people out of their homes and into the metropolitan urban center -- the Fine Arts Museum, the Gardner Museum, the university museums, great libraries, Symphony Hall, professional sports, and a large municipal auditorium with related exhibit and conference spaces. The universities, the State and Federal office centers, the new Boston City Hall, as well as the major hotels together offer further conference and other facilities and meeting spaces. So much for available varieties of outdoor recreation site supply in the Charles.

The availability of the existing supply is appraised in the Tables Nos. 6 through 9. Indicated are the average acres of existing total supply in each municipality per thousand residents, 1965, in that community; the proportion of the total area of each municipality reserved or "dedicated" to outdoor recreation sites, and to "other" additional sites.

TABLE NO. 4

MASSACHUSETTS 1970 OUTDOOR RECREATION SITE INVENTORY

CHARLES RIVER WATERSHED STUDY

NUMBERS OF ACRES PER OWNERSHIP CATEGORY:

TWENTY-NINE MUNICIPALITIES EACH 10% OR MORE IN THE WATERSHED	Grand Total Recreation and Reserved Acres	Municipally con- trolled Subtotal	Town Parks and Recreation Areas	Major Municipal School Sites	Conservation Lands	Town Forests	Municipal Water Dept. Lands	Unclassified Muni- cipal Lands	State Forest and Park Lands	MDC Lands	Other State Controlled Lands	Federal Lands	Private Recreational	Private Non-recreational
Bellingham	225	110	10	100									115	
Belmont	515	195	65	20	70		5	35		30	25		225	40
Boston	4190	2435	1880	180				375		1245	195	65	250	
Brookline	595	440	395	45				55		180			155	
Cambridge	892	272	185	32				15	10		405		130	440
Dedham	1225	230	40	85	60	70	20				165		700	450
Dover	1505	385	230	85	120		10		845				20	255
Franklin	1165	300	125	15	180		40						360	
Holliston	850	490	50	100		160							50	
Hopkinton	100	50	45	5										
Hopkinton	2505	220	5	75	25	115			1995				290	
Lexington	2350	1650	215	285	140		420	590			205	100	280	115
Lincoln	1785	805	175	60	425		140	5	60		600	400	420	100
Medfield	1439	164	35	129									675	
Medway	230	115	30	80	5								115	
Milford	760	600	30	70	250	250	20				10	15	125	25
Millis	305	60	35	5									230	
Natick	1850	600	165	105	50	95	90	95	655		30	100	340	125
Needham	1570	755	105	185		210	180	75		465			260	90
Newton	1840	555	285	175			5	90		280	85		640	280
Norfolk	1955	165	5	70	30	35	25		200		1425		165	
Sherborn	1205	865	10	20	110	635		90			15		325	
Somerville	90	45	35	10						40			5	
Waltham	1690	490	450	40						60	490		370	280
Watertown	345	115	45	15				55		50			90	90
Wellesley	1750	715	170	90	210	185		60		140	15		135	745
Weston	2705	915	90	210	40	485	25	65		600			560	630
Westwood	675	265	80	100	80			5					410	
Wrentham	2240	405	75	95	170		60	5	1235		560		40	
TOTAL	38551	14441	5065	2486	1965	2240	1040	1615	5000	3090	4225	680	7480	3665

TABLE NO. 5

MASSACHUSETTS 1970 OUTDOOR RECREATION SITE INVENTORY

NUMBER OF SITES PER OWNERSHIP CATEGORY: CHARLES RIVER WATERSHED STUDY

TWENTY-NINE MUNICIPALITIES EACH 10% OR MORE IN THE WATERSHED	Grand Total Recreation and Reserved Acres	Municipally con- trolled Subtotal	Town Parks and Recreation Areas	Major Municipal School Sites	Conservation Commission Lands	Town Forests	Municipal Water Dept. Lands	Unclassified Muni- cipal Lands	State Forest and Park Lands	MDC Lands	Other State Controlled Lands	Federal Lands	Private Recreational	Private Non-recreational
Bellingham	8	4	1	3									4	2
Belmont	20	15	6	6	1		1			14	27		2	3
Boston	446	400	214	186							1		2	
Brookline	47	44	33	11									2	
Cambridge	75	69	50	17		1	1	2		3			3	3
Dedham	30	17	5	10					1	2			3	7
Dover	21	12	7	3	1		1				1		5	3
Franklin	8	6	2	1	2		1		1				1	
Holliston	19	14	5	2	6	1							5	
Hopedale	6	5	3	1	1	1							1	
Hopkinton	17	9	3	3	2	1			4				4	3
Lexington	72	59	15	19	6		3	16	1		2	1	7	2
Lincoln	29	14	2	1	7		1	3			1	2	9	
Medfield	14	8	5	3									5	
Medway	12	9	4	4	1						1		3	1
Milford	25	19	6	6	3	2	2					1	4	
Millis	11	7	4	2			1						3	
Natick	57	41	17	14	3	1	2	4	1		1		9	5
Needham	46	33	12	13		1	4	3		2	2		8	1
Newton	82	68	29	20				19		3			5	6
Norfolk	23	11	3	2	4	1	1		1		6		5	
Sherborn	11	8	2	2	2	1		1			1		2	
Sumerville	54	50	31	19						3			1	
Waltham	46	32	29	2			1			2		1	5	4
Watertown	27	21	13	8						1			1	4
Wellesley	45	30	10	12	3	1	1	3		4	2		4	5
Weston	74	34	9	4	3	3	5	10		5	1		21	12
Westwood	23	20	5	6	4		2	3					3	
Wrentham	23	16	5	5	5		1		3		1		2	1
TOTAL	1371	1075	530	385	54	13	28	65	12	40	51	5	126	62

TABLE NO. 6

EXISTING RESERVED ACRES PER MUNICIPALITY

<u>Municipality</u>	<u>Total Acres</u>	<u>Acres Reserved</u>	<u>Reserved % of Total</u>
Bellingham	12,074	225	1.9
Belmont	2,983	515	17.3
Boston	29,058	4190	14.4
Brookline	4,368	595	12.7
Cambridge	4,570	890	18.8
Dedham	6,906	1225	17.7
Dover	9,796	1505	15.4
Franklin	17,282	1165	6.7
Holliston	12,222	850	6.9
Hopedale	3,372	100	3.0
Hopkinton	17,870	2505	14.0
Lexington	10,641	2350	22.0
Lincoln	9,550	1785	18.7
Medfield	9,293	1440	14.1
Medway	7,464	230	3.1
Milford	9,594	760	7.9
Millis	7,849	305	3.9
Natick	10,233	1850	18.1
Needham	8,162	1570	19.2
Newton	11,733	1840	15.7
Norfolk	9,826	1955	19.9
Sherborn	10,959	1205	11.0
Somerville	2,638	90	3.4
Waltham	8,650	1690	19.5
Watertown	2,672	345	12.9
Wellesley	6,730	1750	26.0
Weston	11,111	2705	24.3
Westwood	7,196	675	9.4
Wrentham	14,516	2240	15.4

TABLE NO. 7

EXISTING RECREATION ACRES PER THOUSAND POPULATION

Municipality	1965 Popu- lation	1970 Rec. Acres	Rec.Acres per thous- and Res.	1970 Other Acres	Other Acres per thous- and	Total Acres Reserved
BELLINGHAM	10,604	158	14.9	67	6.3	225
BELMONT	28,794	397	13.8	118	4.9	515
BOSTON	616,326	3,500	5.7	690	1.1	4,190
BROOKLINE	53,608	565	10.5	30	0.6	595
CAMBRIDGE	92,677	376	4.1	516	5.6	892
DEDHAM	26,618	278	10.4	947	35.6	1,225
DOVER	3,512	1,018	289.9	487	138.7	1,505
FRANKLIN	14,721	1,115	75.7	50	3.4	1,165
HOLLISTON	8,915	783	87.8	67	7.5	850
HOPEDALE	4,363	97	22.2	3	0.7	100
HOPKINTON	5,512	2,455	445.4	50	9.1	2,505
LEXINGTON	31,388	830	26.4	1,520	48.4	2,350
LINCOLN	4,463	1,500	336.1	285	63.9	1,785
MEDFIELD	7,429	754	101.4	686	92.3	1,440
MEDWAY	6,869	176	25.6	54	7.9	230
MILFORD	17,034	679	39.9	81	4.8	760
MILLIS	5,262	282	53.6	23	4.4	305
NATICK	30,365	1,440	47.4	410	13.5	1,850
NEEDHAM	29,303	1,102	37.6	468	16.0	1,570
NEWTON	88,514	1,253	14.3	577	6.5	1,840
NORFOLK	3,985	459	115.2	1,496	375.4	1,955
SHERBORN	2,333	1,807	465.9	118	50.6	1,205
SOMERVILLE	86,332	84	0.9	6	0.7	90
WALTHAM	57,134	893	15.6	797	13.9	1,690
WATERTOWN	40,115	190	4.7	155	3.9	345
WELLESLEY	26,297	870	33.1	880	33.5	1,750
WESTON	9,848	1,845	187.3	860	87.3	2,709
WESTWOOD	12,123	604	49.8	71	5.8	675
WRENTHAM	7,517	1,552	206.5	688	91.5	2,240
TOTAL	1,436,796	26,351		12,200		38,550

Table No. 8

EXISTING RECREATION LANDS

(Towns ranked by rounded numbers of recreation acres per
1,000 residents)

Sherborn	466	Franklin	75	Waltham	16
Hopkinton	445	Millis	54	Bellingham	15
Lincoln	336	Westwood	50	Newton	14
Dover	290	Natick	47	Belmont	14
Wrentham	206	Milford	40	Brookline	10
Weston	187	Needham	38	Dedham	10
Norfolk	115	Wellesley	33	Boston	6
Medfield	101	Lexington	26	Watertown	5
Holliston	88	Medway	26	Cambridge	4
		Hopedale	22	Somerville	1

TABLE NO. 9

EXISTING PEOPLE DEMAND ON EXISTING REC'N ACRES

(Towns ranked by persons per reserved acre)

Somerville	959	Waltham	37	Franklin	13
Boston	147	Medway	30	Holliston	11
Cambridge	134	Milford	23	Medfield	6
Watertown	115	Dedham	22	Weston	4
Brookline	97	Needham	19	Wrentham	3
Newton	57	Millis	17	Lincoln	3
Belmont	56	Westwood	17	Dover	2
Bellingham	47	Lexington	16	Hopkinton	2
Hopedale	43	Natick	16	Norfolk	2
		Wellesley	15	Sherborn	2

14. INVENTORY OF THE CHARLES RIVER RECREATION SITE SUPPLY, 1970

Some 1,370 public and semi-public land sites, which together occupy some 38,550 acres in the 29 municipalities principally comprising the Charles River valley, have so far been found and recorded by the Massachusetts Department of Natural Resources, with assistance and cooperation by many other public and semi public agencies.

Intended to have been included in this inventory were all Federal, State, county, municipal, and private but "dedicated" land-holdings of an outdoor recreation nature, or of an educational, religious, historic, or other institutional nature if the site had appreciable acreage of reasonable recreational potential. One acre is the minimum site size.

The site category perhaps only 75-80 percent completed at this time is private enterprise recreational lands. Not recorded may be some proprietary golf lands, including golf-driving ranges, and there may be fee-paying family camping grounds and motel or trailer-court facilities not recorded.

Domestic back-yard swimming pools could not be estimated from a March-April 1970 metropolitan Boston structural sample household interview survey, conducted in part for the Massachusetts Department of Natural Resources. Such pools are not separately summarized in municipal assessors' annual returns to the Commonwealth of Massachusetts.

Counted in the "private but dedicated" recreation sites, are all lands owned by the Massachusetts Audubon Society, the Trustees of Reservations, and like bodies, such as Boy Scout, Girl Scout and YMCA/YWCA camps and reservations.

The governmentally owned lands are believed to be recorded with 95 percent completeness or better.

Excluded from inventory and tabulation were all cemeteries, sewage treatment sites, and most private and municipal medical, surgical, and general hospital sites, regardless of acreage.

The large acreages at some mental hospitals and other institutions such as the Working Boys' Home or the New England Peabody Home for Crippled Children are included because they have outdoor recreation values both for their institutional residents and for other people who

may come to those sites. Outdoor recreation values for the handicapped importantly include recreational association on-site with non-handicapped or less-handicapped or differently-handicapped persons and their families.

For each of the more than 1,300 sites tabulated, there is on file in the planning office of the Massachusetts Department of Natural Resources a five-page form recording at least the site name, location, ownership, administration, principal activity and approximate overall acreage. Not many of the Charles River forms as yet have much additional data on activity potentials nor on numbers and kinds of specific recreation facilities on each site.

Arrangements have been made for machine data handling and for periodic up-dating and enlargement of site inventory forms. Print-outs of all site data will be available at print-out cost to units of government and to other serious enquirers .

DEMAND FOR OUTDOOR RECREATION

15. PHILOSOPHY OF "DEMAND"

Attempting to define "demand" or "supply" entails attempting to define "outdoor recreation". The existence of man in numbers in urban circumstances with leisure time appears to be the basis for any concept of "outdoor recreation". The heart of it seems to be human beings simply being out-of-doors in activity or in passivity for their own enjoyment. The range of outdoor recreation is as broad as human life. For there to be opportunities for a range of such experiences, there must be some corresponding range of spaces available, each in some degree "dedicated" to human recreational usage by expressed purpose or ownership or both.

Human recreation demands are almost infinitely elastic; they vary with the supply and the resources, and currently outrun them. Skiing, whether on water, snow, sand, pine needles, steep wet grassy banks, or dry plastic pellets, merely represents interaction of human demand with available supply and natural resources.

Also, the mere existence of a natural resource feature (often topographic or vegetative) unusual in its surrounding territory, seems universally to prompt in humans both exploitational and preservational demands.

On the modest physiographic scale of the Charles River and Neponset River watersheds, such "demands" resulted in American Indian ascriptions of "reservation", even "holiness", to notable hills and springs and prominent rocks -- to wit, Great Blue Hill, Milton; Pegan Hill, Natick; Rocky Narrows, Sherborn/Dover; and Hemlock Gorge, Needham/Newton, to mention only a few. Following British colonization of the Charles and environs, the above-named and many other locations have been, in varying degree, preserved as human recreation resources through three and a half centuries of urbanization. This implies "demand" for further and more extensive protection, preservation and perpetuation of other historic and natural or little-altered features of the Charles River valley landscape. But "protection" and "preservation" from what? . . . by whom? . . . for what purpose? Man, of course: to be protected from and to be used and enjoyed by -- man.

Open spaces of many kinds are a consequence and concomitant of urbanization. Some of them are functionally necessary within the urban-scape, others may be farther away, depending on the physical means and the economics of the forms of transportation available.

At neighborhood and municipal levels of concern in the urban world today functionally necessary spaces include school sites, playgrounds (with or separate from schools), and usually some kind of central green as community identifying "badge".

At either municipal or inter-municipal district levels, given 20th century technology, functionally necessary open spaces include cemeteries, hospital, college and university sites, water catchment and water storage areas, sewage disposal and solid waste disposal areas, also transportation spaces.

Then there come into action the human in-born preservational and exploitational tendencies. An almost unspoken union of community sentiment impels public preservation of notable landscape features and scenic areas, as mentioned at the opening of this chapter. And, in a mainly private enterprise society, there are offered to or dumped on the community, the wet, rocky or remote land areas least easy to develop at given stages of urban growth.

Large-area public preservations appear to take place at levels of government more or less commensurate with the geographic extent, the ascribed "importance", and the magnitude of cost of the particular preservation. Where a convenient vehicle for such actions does not yet exist, one is adapted, or invented. In Massachusetts,

for example, the Trustees of Reservations and the Metropolitan Parks, Water and Sewer Districts.

Although geographically more remote, the functional foundations of urbanization are, of course, the farms, fields, forests, mines and fisheries that supply food, fuel, fibre and building materials for the urban inhabitants and their roads, railways, airports and buildings.

So far as the foregoing considerations bear on making the 1970 Massachusetts statewide outdoor recreation plan, the constantly asked (and unasked) question is "how far, how widely, shall overt; concentrated urbanization extend in Massachusetts?" And accompanying are questions about how far as a community and a society we wish by conscious public controls to direct and form and punctuate our urbanization with dedicated open spaces. Answers to these questions in the U. S. A. and in Massachusetts will continue to come mainly by successive legislative enactments at Federal, State, and municipal levels.

16. DIMENSIONS OF DEMAND

In this 20th century, the three basic dimensions of outdoor recreation demand are the numbers, kinds, and locations of outdoor resource features; the numbers, kinds, and locations of humans desiring to visit or use the resources; and the varying command of leisure time and means of transportation to reach whatever are the developed "supply" of outdoor recreation natural resource features.

Outdoor recreation in the 19th and 20th centuries, world-wide, has shared in the "revolution of rising expectations" impelled by increasing technological productivity and the continuing diffusion of real leisure and real income. The more economically advanced, the greater the acceleration in breadth of demand for outdoor recreation opportunities, and the greater the usage of existing sites and facilities. Thus, there is now a socio-economic "participation rate" factor in outdoor recreation demand, as well as all the former aspects of population numbers, sex, age-groups, incomes and personal activity choice preferences. These factors are commonly examined in terms of the locally resident population.

Visitor (non local) demand is about to change by something like a quantum jump. In 1970, for the first time in mass passenger transportation, the 12 hour world is here. The jumbo jet makes possible week-end and longer visitation of the Charles River valley and environs

from Asia as readily as from all of Europe. Week-end and week-long skiing vacations in Switzerland are beginning to be as common among Boston area residents as were week-end and week-long White Mountain skiing vacations by snow train thirty-five years ago.

Plainly some large portion of usage of outdoor recreation sites in the Charles watershed will continue for some years to be mainly by persons rather locally resident, say within zero to fifteen or twenty-five miles. However, our Charles River world-wide premier institutions in finance, law, medicine, government, engineering, higher education, and fine arts will draw increasing numbers of visitors from far away. At some locations, the numbers from out-of-state could soon equal or exceed the numbers from Massachusetts, as they do already at times in our Berkshire Region, and at the Cape Cod National Seashore, and, as in 1975 and onward, they will at Minute Man National Historic Park. Thus there is a new need to be not too parochial in trying to estimate the dimensions of outdoor recreation demand in the Charles River watershed.

A counter-factor to keep in mind is the thought that neither Charles River residents nor their 9-month collegiate student guests (about 100,000 in number) expect to satisfy all of their outdoor recreational desires and demands within the valley. This is demonstrated by Charles River residents' vacation home ownerships (and rentals) elsewhere in Massachusetts, New England, eastern Canada, the Carolinas, Georgia, Florida, the Caribbean, the Mediterranean, even castles in Spain, chateaux in France, Chalets in Switzerland and stately homes in England. The 12-hour world is here!

17. POPULATION NUMBERS

Four times as many people live in the Charles River watershed as a century ago. That population growth is tabulated next page from the Commonwealth of Massachusetts Census, which is taken decennially in the years ending in "5". The numbers tabulated are those for the whole of each municipality, although only a portion of it may be geographically and topographically in the watershed. There is acknowledged uncertainty about the exactness of the numbers reported, especially in the principal cities, but the directions of change of the numbers are generally accepted.

The populations of the whole (not the watershed part) of thirty-four Charles River municipalities are tabulated. Foxborough, 99.8 percent by area outside the Charles watershed, was omitted. So far

as outdoor recreation demand depends on sheer numbers of local residents, it is noted that the major changes in populations by groups of watershed municipalities during the past century have been as follows:

<u>1865 - 1945</u>	<u>Upper Charles (18 towns)</u>	<u>1945 - 1965</u>
grew nearly 4 times		doubled again
	<u>Middle Charles (8 towns)</u>	
grew 5-1/2 times		grew 50%
	<u>Inner Suburbs (3 towns, 1 city)</u>	
grew 11 times		grew 10%
	<u>Inner Core (3 cities, 1 town)</u>	
grew 3-1/3 times		declined 15%

Paralleling this geographic population growth pattern, it is notable that the Metropolitan Parks District was chartered in 1897 and soon after acquired its principal two reservations -- Blue Hills and Middlesex Fells -- and much of both banks of the Charles River in and between Boston and South Natick, in the sixteen municipalities of the Lower and Middle Charles.

And now that the residential population growth pressure since 1945 is farther up-river, lively interest in additional river-bank protection, pollution abatement, and wetlands preservation is evidenced through the Leagues of Women Voters in the 18-town Charles River Group, and through the Citizens' Advisory Committee on the Corps of Engineers Charles River Study of 1966-1971. Perhaps such interests may also be said to parallel demand for outdoor recreation as evidenced in part by land purchases by Charles River cities and towns with State and Federal financial aid since 1945 and 1955 notably through municipal school boards and through municipal conservation commissions. Municipal, county and state capital outlays for outdoor recreation site acquisition and development become voted only in response to "felt" demands, necessarily related mainly to the resident population of the voting jurisdiction. At this writing, the demand is ever upward in sheer numbers of persons resident in or near the Charles River watershed.

TABLE NO. 10

POPULATION GROWTH & CHANGE IN THE CHARLES RIVER VALLEY

<u>Municipality</u>	<u>Year</u> <u>Estab.</u>	Sq. Mi. <u>Total</u> <u>Area #</u>	Massachusetts State Census Data				(Est.) <u>1985</u>
			<u>1865</u>	<u>1915</u>	<u>1945</u>	<u>1965</u>	

Inner Core

Boston*	1630	45.40	268,626	745,439	766,386	616,326	705,000
Brookline	1705	6.82	5,262	33,490	56,940	53,608	58,000
Cambridge	1636	7.14	29,112	108,822	111,124	92,677	98,000
Somerville	1842	4.12	9,353	86,854	105,883	86,332	92,000

Subtotals 63.48# 312,353 974,605 1,040,333 848,943 953,000

*Combined 1865 population includes municipalities annexed by Boston 1868 et seq.

Inner Suburbs

Arlington	1807	5.58	2,760	14,889	43,515	52,482	60,000
Belmont	1859	4.66	1,279	8,081	28,866	28,794	32,000
Newton	1691	18.33	8,975	43,113	77,257	88,514	101,000
Watertown	1630	4.17	3,779	16,515	37,438	40,115	45,000

Subtotals 32.74# 16,793 82,598 187,076 209,905 218,000

Middle Suburbs

Dedham	1636	10.79	7,195	11,043	16,659	26,618	32,000
Lexington	1713	16.63	2,220	5,538	14,452	31,388	36,000
Lincoln	1754	14.92	711	1,310	1,998	4,463	8,500
Needham	1711	12.75	2,793	6,542	14,507	29,303	33,000
Waltham	1738	13.52	6,896	30,154	43,577	57,134	64,500
Wellesley	1881	10.51	--	6,439	17,581	26,297	32,000
Weston	1712	17.36	1,231	2,342	4,473	9,848	12,500
Westwood	1897	11.24	--	1,448	4,797	12,123	16,000

Subtotals 107.72# 21,046 64,816 118,044 197,174 236,500

Upper Charles

(continued next page)

#Total area of municipality -- not watershed portion

TABLE NO. 10 (Cont'd)

POPULATION GROWTH & CHANGE IN THE CHARLES RIVER VALLEY

<u>Municipality</u>	<u>Year</u> <u>Estab.</u>	<u>Sq. Mi.</u> <u>Total</u> <u>Area #</u>	<u>Massachusetts State Census Data</u>				<u>(Est.)</u> <u>1985</u>
			<u>1865</u>	<u>1915</u>	<u>1945</u>	<u>1965</u>	
<u>Upper Charles</u>							
Ashland	1846	12.96	1,702	2,005	2,920	8,698	12,000
Bellingham	1719	18.86	1,240	1,953	3,494	10,604	15,000
Dover	1784	15.31	616	999	1,566	3,592	6,500
Franklin	1778	27.00	2,510	6,440	7,531	14,721	20,000
Holliston	1724	19.10	3,125	2,788	3,311	8,915	14,000
Hopedale	1886	5.27	--	2,663	3,317	4,363	6,000
Hopkinton	1715	27.92	4,132	2,475	2,856	5,512	9,000
Medfield	1650	14.52	1,012	3,648	4,199	7,479	10,000
Medway	1713	11.66	3,219	2,846	3,363	6,869	10,500
Mendon	1667	17.94	1,207	933	1,504	2,310	4,000
Milford	1780	14.99	9,108	13,684	15,801	17,034	21,000
Millis	1885	12.26	--	1,442	2,329	5,262	9,000
Natick	1650	15.99	5,208	11,119	15,789	30,365	35,000
Norfolk	1870	15.35	--	1,268	2,006	3,985	6,500
Sherborn	1674	15.39	1,049	1,696	1,036	2,333	6,000
Walpole	1724	21.09	2,018	5,490	8,409	16,390	22,000
Wayland	1835	15.88	1,137	2,033	3,901	12,192	16,000
Wrentham	1673	22.68	3,072	2,414	5,097	7,517	12,000
Subtotals		304.17#	40,355	65,896	88,429	168,141	234,500
Grand Totals		508.11#	367,855	1,187,915	1,433,882	1,424,163	1,642,000

Total area of municipality -- not watershed portion

Visitor demands for outdoor recreation are particularly heavy in the 8 municipalities of the Lower Charles (the Inner Suburbs and Inner Core), downstream of Moody Street Dam, Waltham. To this portion of the watershed come more than 1,000,000 commuters daily from all over eastern Massachusetts and from out-of-state. They come to work, shop, go to school or college, go to clinics and hospitals, visit government offices, professional offices, banks, hotels, theatres, museums, libraries, restaurants, and transportation terminals.

Commuters and out-of-state visitors in 1965 out-numbered the Lower Charles residents more than one-to-one. They impose day-time and week-day short-term demands for special kinds of outdoor recreation and environmental conservation as great or greater than those of the local residents. The jumbo jet aircraft and eastern United States interest in the bi-centennial of American independence, 1975-1976, will further expand and increase the numbers and territory experiencing heavy visitor demand in the Charles River watershed.

Table No. 10 also shows tentative population numbers for Charles River cities and towns in 1985. These are adjusted and blended principally from three projections: one by the Massachusetts Department of Administration and Finance for 1975; one by the Metropolitan Area Planning Council, Boston, for 1975 and 1990; and one by the U. S. Army, Corps of Engineers, New England Division, Waltham for 1980, 2000, and 2020 in their Northeastern Water Resources Study. Our 1985 projection (estimate) may likely prove low; a watershed total growth of only 15 percent is projected over the next 15 years. A national growth of some 50 percent has been projected by the U. S. Census Bureau for the 35 years between 1965 and 2000 A. D. However, our Charles River projection is closely related to availability of buildable land, of water and sewerage, of transportation and highways, of jobs, and to life-style preferences demonstrated by current Charles River watershed dwelling owners and dwelling renters.

And our Charles projection to 1985 has been checked against county-cluster control totals and growth rates projected throughout the 150 county megalopolis by the U. S. Office of Business Economics, and by the New York Regional Plan, Inc., also - the Economic Research Service of the U. S. Department of Agriculture.

18. AGE-GROUPS

The population age-groups 15-25 or 14-24 are widely reported major participators in outdoor recreation. This was brought out

in the great U. S. Outdoor Recreation Resources Review studies of 1960 et seq.

In the half-century 1920-1969, while the total resident population of the U. S. A. virtually doubled, and remained about the same percent of the total population, as reported in rounded numbers by the U. S. Census (000 omitted):

<u>Year</u>	<u>Total Pop'n</u>	<u>Youths 14 yrs - 24 yrs</u>	
		<u>Numbers</u>	<u>Percent</u>
1969	203,216	39,068	19.2
1940	131,669	26,327	20.0
1920	105,711	20,754	19.6

Nationally, in that half-century, non-white youths slightly more than doubled in number and white youths slightly less than doubled: (U. S. Census: 000 omitted):

<u>Year</u>	<u>White Youths 14-24 yrs</u>	<u>Negro & Other Races Youths 14-24 yrs</u>
1969	33,903	5,165
1920	<u>18,291</u>	<u>2,386</u>
Increase	15,612	2,779
% of 1920	85.3%	116.4%

The outdoor recreation demands and desires of the 14-24 year old group are satisfied in part at school or college, and in part elsewhere. Many of the most organized and active participation competitive sports take place on school - and college - provided playing fields and athletic facilities. Nationally, about 15 percent of all youths 14-24 years of age were reported in college in 1968, about 42 percent in school, and 43 percent not enrolled, per U. S. Census (000 omitted):

<u>Year</u>	<u>All 14-24 yrs</u>	<u>In College</u>	<u>In School</u>	<u>Not Enrolled</u>
1968	35,546	5,637	14,785	15,123
1945	19,980	730	7,430	11,820

So far as the Charles watershed population parallels the national patterns above reported, some 20 percent of the current residents are of 14-24 years age, and as many of them are not enrolled as are attending high and junior high schools in the area. Special attention to this

aspect is needed in recreation programming and facilities by all agencies. Merely providing recreation land spaces is not enough to harness some of the energies of these youths.

The foregoing data are selected from a current population report by the U. S. Census, Series P-23, No. 30, "Characteristics of American Youth", 6 February 1970.

Approximately parallel figures for the youth and total population and school and college enrollees in the 29 municipalities 10 percent or more by area within the Charles River watershed are summarized below from a detailed table and discussion overleaf:

<u>Year</u>	<u>Resid. Pop</u>	<u>15-24 yrs</u>	<u>Est. in College</u>	<u>Town Hi Sch</u>
1965	1,333,120	193,705	30,610	48,290

Importantly missing from Table No. 11 are 1965 (or 1967) enrollments of Charles River resident youth aged 15-24 in private or parochial schools, wherever situated. These have not been found.

Local enrollments of the specified age-group at such schools located in the Charles watershed would help plug the gap, but are difficult to secure, and would still be incomplete.

Youths 14-24 years of age were estimated by the U. S. Census Bureau as some 19 percent of the national resident population in 1969, p. 34.

Youths 15-24 years of age were reported nearly 15 percent of the 29 Charles River municipalities aggregate population, per Massachusetts State Census, 1965, p. 36, first two columns. 193,705 such youths are recorded.

There are in addition some 70,000 visiting collegiate students, enrolled at Charles River valley degree-granting colleges and universities, who are resident 9 to 12 months each year for study or graduate study. Some 118,000 total collegiate students were reported so enrolled in 1965 by the fact book of the New England Board of Higher Education, but from that number, we deduct the 48,000 local collegiate youth portion of the Charles resident population.

In 1970 in the Charles study area, the youthful major participators in outdoor recreation aged 14-24 years probably number in the range of 265,000 to 275,000 persons, with some 1,000,000 other older resident

adults, and more than 100,000 younger children. This is one set of dimensions of outdoor recreation demand.

19. INCOMES

Personal and family incomes also importantly influence outdoor recreation demand. Massachusetts shares with states bordering to the south and west in being part of the richest and still most populous region of the entire continental United States.

In 1960, the U. S. national median family income was reported \$5,660 per annum. The corresponding figure in Massachusetts was \$6,272; some 10 percent above the national median. Massachusetts is favored also in the upper and lower segments of family incomes reported for 1960 were as follows:

Under \$3,000 per year		Over \$10,000 per year
Massachusetts	12.4%	17.0%
U. S. A.	21.4%	15.1%

There was a small county range of Massachusetts family incomes in 1960 compared to the range by counties in U. S. A.

Under \$3,000 per year		Median	Over \$10,000 per year
<u>Massachusetts</u>			
Norfolk County	7.3%	\$7,366	---
Dukes County	23.0%	4,745	6.6%
<u>United States</u>			
<u>Alabama</u>			
Hunter County	72.1%	1,387	2.6%
<u>New York</u>			
Nassau County	---	8,515	37.6%

The 1960 distribution of annual family incomes and income-ranges in Massachusetts was representative within the eight megalopolitan States in the U. S. Bureau of Outdoor Recreation Northeast Region.

TABLE NO. 11
YOUTH POPULATION AND ENROLLMENTS, 1965 era
CHARLES RIVER WATERSHED STUDY

<u>Municipality</u>	<u>Res. Pop</u> (1)	<u>Ages 15-24</u> (1)	<u>Est. Coll.</u> (2)	<u>Sr. Hi.</u> (3)
Bellingham	10,605	1,440	245	990
Belmont	28,795	4,100	665	1,000
Boston	616,325	87,810	14,235	16,195
Brookline	53,610	8,080	1,240	2,365
Cambridge	92,675	14,035	2,145	2,835
Dedham	26,620	3,910	615	1,670
Dover	3,510	510	80	150
Franklin	14,720	1,820	340	100
Holliston	8,915	1,170	205	695
Hopedale	4,365	585	100	470
Hopkinton	5,510	885	125	710
Lexington	31,390	4,010	560	2,685
Lincoln	5,615 (4)	680	130	---
Medfield	7,430	945	170	610
Medway	6,870	1,790	160	860
Milford	17,035	2,560	390	850
Millis	5,260	675	120	290
Natick	30,365	4,205	700	1,645
Needham	29,305	3,940	675	1,650
Newton	88,515	13,455	2,045	4,180
Norfolk	3,985	640	90	---
Sherborn	2,335	320	55	---
Somerville	86,330	12,405	1,990	2,040
Waltham	57,135	9,315	1,320	1,905
Watertown	40,115	5,985	925	1,345
Wellesley	26,295	3,995	605	1,385
Weston	9,850	1,675	225	810
Westwood	12,125	1,680	280	855
Wrentham	7,515	1,085	175	---
TOTALS	1,333,120	193,705	30,610	48,290

It is recognized that the April 1967 "Outdoor Recreation Trends" tabulations published by the U.S. Bureau of Outdoor Recreation refer to a population 12 years of age and older in 1965.

1. 1965 Massachusetts State Census
2. 1965 Massachusetts residents enrolled in college anywhere averaged 23.1 per thousand resident population, per U. S. Department of Education.
3. 1967 Municipal Senior High School enrollments, per Massachusetts Department of Education.
4. Town of Lincoln residents, 1960 census, including families in Federal housing on the airbase, whose children attend a town operated school.

<u>State</u>	<u>Under \$3,000</u>	<u>Median</u>	<u>Over \$10,000</u>
Connecticut	9.8%	\$6,887	22.1%
Delaware	16.0	6,197	19.6
Maryland	15.2	6,309	19.8
Massachusetts	12.4	6,272	17.0
New Jersey	11.4	6,786	22.0
New York	13.8	6,371	19.9
Pennsylvania	16.8	5,719	13.9
Rhode Island	16.8	5,589	11.7
United States	21.4	5,660	15.1

Between 1960 and 1969, apart from inflation, there has been an appreciable shift in the national distribution of family incomes. The U. S. Department of Commerce reporting from a July 1969 sample survey of households nationwide, indicated total money incomes before taxes of primary families or individuals in the 12 months immediately preceding initial interview, as follows:

ANNUAL FAMILY INCOMES SURVEY July 1969

<u>Incomes</u>	<u>Percent of Survey Households</u>	<u>Est. No. Households</u>
Under \$3,000	20.0	12.4 million
\$3,000 - \$4,999	15.1	9.3
\$5,000 - \$7,499	19.3	12.0
\$7,500 - \$9,999	15.9	9.9
\$10,000 and over	25.9	16.0
Not reported	3.9	2.4

The data show a modest reduction in number of low income families, and substantial increases in the numbers of moderate, middle, and upper income families, compared with 1960. This was brought about in part by two great economic developments, as well as by legislated changes in health, education, employment and welfare programs.

The first great change was from partial employment to nearly full employment in the labor force. in 1960 there were 54 million non-farm job-holders, but more than 70 million in 1969. The national population expanded some 12% in that period, but non-farm employment increased

30 percent, two and a half times the rate of population increase. Massachusetts shared in the non-farm job expansion, and accompanying increase in total spendable real incomes, which generates new demands on existing outdoor recreation sites and facilities.

The second great change was that by 1969 consumer dollar expenditures for "services" were more than \$242 billion, nearly double the 1960 aggregate dollar spending in this general category. During the period 1960-1969, dollar inflation was only 13% by labor cost per unit of output for all manufacturing, or 20% by purchasing power index.

Since the end of World War II, the domestic economy of the United States has shifted to the fulfillment of demands for services, including outdoor recreation, rather than goods. The proliferation in ski-slopes, chalets, vacation homes, tours, marinas, motels, inns and restaurants, and all of vacation travel and tourism attest to this shift. Standard & Poor indicate personal recreation spending was some \$18 billion in 1960 and more than \$36 billion in 1969.

At this time in the United States, "more than half of the employed population is not involved in the production of food, clothing, automobiles, or other tangible goods". (Victor Fuchs, The Service Economy) Here, too, Massachusetts has been sharing in, if not leading, the shift from older style durables to newer consumables such as pre-cooked foods, throw-away, non-woven items for use in offices, automobile services, hospital services, also the great research efforts for NASA and for other basic and applied uses of new scientific knowledge.

There has also been a sharp rise in prices for services, reflecting the rise in cost of labor, principal element in service costs. The converse of this payroll cost-push is that the larger numbers of people employed have more money now for "discretionary" spending than they ever had before, despite the inflationary bite on their dollars. This exhibits itself in greatly increased visitation to our State and national parks right here in Massachusetts.

Notwithstanding current efforts to "cool" the United States economy, the outlook is for sustained diffusion of real income and real leisure in Massachusetts and surrounding States within the rich and populous north-east region. The attitude of this element of outdoor recreation demand is upward.

20. OUTDOOR RECREATION DEMANDS AND ACTIVITY PREFERENCES

In the Charles, to the frame of nineteen national summer outdoor recreation activities, identified in TRENDS, there must be added a twentieth: recreational visiting of cultural and historic sites in large numbers by Massachusetts, New England and out-of-New England visitors, principally from the eastern United States and eastern Canada. The combined demands of all kinds fall on sites in the Charles River watershed as on other sites in eastern Massachusetts. Particularly in the Charles study area there is need to distinguish where possible between local residents demands and the demands made in the valley by commuters, and by the many, many visitors from out-of-valley and out-of-State.

For example, visitors to the U. S. S Constitution, "Old Ironsides", at Charlestown Navy Yard number in the range of 700,000 per year, mostly in the four summer months, it is reported.

The bare watershed population of the Charles in 1965 was some 829,000 residents as estimated by the Corps of Engineers. They lived in a territory one-half mile to five miles wide each side of the river, extending from South Natick Dam 15 crow-flight miles southwesterly to Hopedale and Milford, also 15 miles northeasterly to Charlestown. But within 15 miles full circle from South Natick Dam lived some 1,764,765 people in 1965, and within 50 miles radius, more than 5,250,000. See Table No. 13.

In this large and near-at-hand population context, continuing and substantial non-local visitation of Charles River watershed outdoor recreation resources must be expected, especially at sites of unusual characteristics, such as Hemlock Gorge, with its Echo Bridge, or Lake Waban with both Wellesley College and the Hunnewell topiary garden.

Among the 19 (or 20) recreation activities highlighted in the 1967 TRENDS survey report, 15 showed marked increase of demand over 1960, 2 showed barely reduced demand (hunting, spectator sports) and 2 showed appreciably reduced demand (automobiling, horseback-riding).

Large participation increases 1960-1965 in outdoor recreation activities were reported as follows:

21. PARTICIPATION PERCENT CHANGES 1960-1965 TRENDS
REPORT (PAGES 22-23-24 APRIL 1967)

Skiing	115	Ice-skating	38
Bicycling	92	Participation sports	37
Canoeing	62	Camping	35
Sailing	62	Spectator Sports	35
Pleasure Walking	57	Outdoor Concerts	32
Sledding	55	Hiking	26
Horseback Riding	44	Sightseeing	26

The Charles River watershed has good existing sites and facilities in each of the above 14 outdoor recreation activities that have shown the largest participation increases nationally. And the Charles has good potential areas for additional such sites and facilities. Skiing, both at Great Blue Hill and at Franklin, is assured by snow-making and smoothing equipment. Skating (on man-made ice) is available at increasing numbers of sites in the Charles and environs, 24 of them in the Metropolitan Parks District, alone.

In the Charles the foregoing activities are all mainly of local interest and for resident participation.

NEED FOR OUTDOOR RECREATION

22. DEMANDS ON THE ENVIRONMENT

In the Charles River watershed, and throughout eastern Massachusetts in the past hundred years there have occurred important changes in the resident population numbers and in the outdoor recreation demands by the residents on their geographic environment.

Relating 1865 population numbers, (some 207,700) and the 1865 geography of urban areas to the 307 square mile Charles River watershed and to the 2,300 square mile land and water area of eastern Massachusetts, one notes the then prevailing assumption of an almost "limitless" environment of fields, farms, pastures, and woods immediately (and forever?) available at the very boundary of each then-existing urban cluster.

Some 76 square miles, nearly 1/4 of the whole Charles River valley, in 1965 was built up with urban streets, houses, schools, stores, hospitals, colleges, governmental offices, etc., whereas in 1865 scarcely 38 square miles were thus built-up.

Accompanying this doubling of the deeply urbanized area in the valley, came great changes from local farming and near local self

TABLE NO. 12

1965 Population in 15 Mile Full-Circle

Acton (1/2)	5,095	Milford	17,035
Arlington	52,480	Millis	5,260
Ashland	8,700	Milton	27,710
Bedford (1/2)	5,395	Natick	30,365
Belmont	28,795	Needham	29,305
Bellingham	10,605	Newton	88,515
Boston	616,325	Norfolk	3,985
Brookline	53,610	Norwood	28,980
Cambridge	92,675	Randolph (1/2)	10,865
Canton	15,310	Sharon	11,340
Concord	14,515	Sherborn	2,335
Dedham	26,615	Somerville	86,330
Dover	3,510	Southborough	4,780
Foxboro (1/3)	4,075	Sudbury	10,895
Framingham	52,370	Stoughton (1/2)	9,845
Franklin	14,720	Stow (1/2)	1,595
Holliston	8,915	Watertown	40,115
Hopkinton	5,510	Waltham	57,135
Hopedale	4,365	Walpole	16,390
Hudson (1/2)	6,820	Wayland	12,190
Lexington	31,390	Wellesley	26,295
Lincoln	5,615	Weston	9,850
Marlboro	23,590	Westwood	12,125
Maynard	9,070	Winchester	21,635
Medfield	7,430	Woburn (1/2)	17,575
Medford	60,430	Wrentham	7,515
Medway	6,870		

Circle Total, say 1,764,765

1965 Population in 50 Mile Circle

609,910	Worcester
609,000	Essex
1,280,200	Middlesex
706,200	Suffolk
560,100	Norfolk
415,240	Bristol
292,700	Plymouth
<u>4,470,000</u>	
180,000	(Conn/N.H. parts)
<u>800,000</u>	(R.I. part)
5,350,000	Circle Total

sufficiency to a high degree of industrial, commercial, and agricultural specialization. Outdoor occupations diminished and indoor occupations became ever larger and more concentrated, both in the Charles and throughout the eastern United States.

Thus in 1965, and now, most residents in the Charles River watershed live and work indoors and commute to work in closed vehicles. A century ago, the much smaller population lived (and more of them worked) in more direct contact with a less urbanized and more immediately available out-of-doors environment.

Suddenly, it is now being widely perceived that the former "limitless" open environment in the United States is going or gone. Throughout eastern Massachusetts, and particularly the Charles River valley, there is need to identify, select, and protect, by a number of kinds of actions, available outdoor recreation opportunities and other elements of the remaining natural environment in the valley. There is need to select and protect those opportunities and elements, the conservation of which will effectively and importantly promote the long-term local and regional and State and national welfare.

A consequent need is for criteria by which to select the physical areas and the environmental elements proposed to be preserved, as well as selecting preservation actions, methods and financing proposed.

Three practical and usual and serviceable site selection and environmental protection criteria are the following:

- 1) degree of threat of loss of the resource;
- 2) degree of social need for preservation action at a locus;
- 3) degree of fulfillment of some rationalized standard or standards for outdoor recreation spaces and for environmental qualities in the Massachusetts urbanizing region.

On the application in eastern Massachusetts and the Charles River valley of each of the foregoing criteria, the following comments are offered:

- 1) The centuries-long record of multi-nucleated urbanization in the study area demonstrates that, except for lands and waters specifically protected, every natural resource acre is threatened, and, in time, will be lost -- i. e., covered or converted to urbanized use by one or more of the works of man. There are in the Charles study area only degrees of time immediacy of such loss.

- 2) At least three kinds of social need require recognition (there may prove to be more):
 - a) concentration of children, and of older people, for whom there is little or no safe, effective public, local outdoor recreation space within a safe, short walk of their dwelling (5 to 10 minutes = 1/8 to 1/4 mile, not crossing any major traffic street);
 - b) need, in existing (or new) outdoor recreation places, local or regional, of provision for handicapped or specially disadvantaged persons (crippled, diseased, deformed, retarded, or very young or very old);
 - c) concentrations of residents lacking means of access to regional outdoor recreation lands or outdoor Cultural events sites;
- 3) Fulfilling some rational standard(s) for outdoor recreation spaces and other reserved spaces requires first finding or developing such standards for Massachusetts, and to this the next paragraphs are devoted.

23. SPACE STANDARDS

From fifteen or more sources summarized in the U. S. Bureau of Outdoor Recreation 1967 publication "Outdoor Recreation Space Standards", we derive several successive elements:

- a) for playgrounds, playfields and neighborhood parks, combined, an average (from 8 and 9 sources) of 6.7 acres per thousand resident population;
- b) for municipal parks and recreation areas, (from sixteen sources) an average of 9.7 acres per thousand resident population;
- c) for sub-state regional parks, (fifteen sources) an average of 15.5 acres per thousand resident population;
- d) for state provided recreation areas, (six sources) about 40 acres per thousand resident population.

Adding those four elements together yields an over-all average open space standard of 71.9, which we round off to 70.0 acres per

thousand resident population. Interesting confirmation from within the 1967 booklet is that three other sources together average 76.9 acres per thousand resident population for all recreation lands within any one region at all levels of responsibility, combined; the median of these three was 70.0 acres per thousand.

Applying this standard to the Charles River watershed 1965 aggregate total population (1,424,163), there should be reserved within the 29 valley municipalities some 99,690 acres for outdoor recreation of all types at all levels of responsibility. Currently reserved for recreation are only some 26,350 acres (Table No. 7), about 1/4 of the BOR compiled standard.*

Dividing the existing reservations by the 1965 population, the existing (although inadequate) standard is some 18.3 acres per thousand resident population, all activities and passivities combined. Purposely not counted above are the 12,200 acres for institutional functions, actual school building sites, water resource lands, and unclassified municipal lands. Most of these have only indirect outdoor recreation value. In some cases other use is prohibited by law or by public policy.

The average recreation acres per thousand population, town by town, are shown in Table No. 8. Depending on the chance of the location of a State or Federal property within any municipality, a few have very high existing recreation space ratios, but most are moderate to low, in the Charles River study area, compared with either the BOR standards or the Charles River existing average.

The American Recreation Association for many years has suggested a generalized number of 10 acres open space per thousand population. Plainly the minimum figure applicable in the Charles should be in the range of 20 acres per thousand, of which 18.3 is existing and 1.7 a small addition from the 12,200 "other" acres reserved, which average 8.56 acres per thousand over the whole study area.

A reasonable figure between the BOR 70 and the existing 20 could be 30 acres per thousand population. This is the sub-total of BOR summarized neighborhood, municipal and sub-state regional parks, based on reports from 8, 9, 15, and 16 sources.

24. ADDITIONAL RECREATION SPACES REQUIRED

Merely to bring the lower ratio Charles River municipalities up to the 20 acre average in respect of their 1965 population would require finding and designating some 14,300 additional acres, partly within the low-ratio municipalities, partly elsewhere in the valley.

*Assumes demand to be met from within the watershed and the contiguous area

To provide for the increase of 218,000 Charles resident population in the next fifteen years (Table Nos. 10 and 11) at a variety of measures, additional 4,360 acres minimum, or 6,478 acres at the 30 acre standard.

To bring recreation-reserved areas in the whole Charles valley up to the 30 acre standard by 1985, would require finding and protecting 22,900 added acres. With the existing stock, this would make a total of 49,250 reserved acres or more. Such an addition is less than 50 percent of the 70 acre standard derived from the BOR 1967 compilation. To apply the BOR standard would require adding 46,667 acres, nearly 1/5 of the 29 municipality gross area.

25. ASSERTED NEED AND POSSIBLE PROGRAM

The prior discussion of outdoor recreation space standards and of resulting numbers of added reserved acres needed in the Charles is founded on the two re-iterated basic assertions of need, without any early limit in time:

1) the environmental resource threat posed by on-going urbanization in the Charles and in eastern Massachusetts justifies "saving" any and every natural resource acre that can be saved, low or high, wet or dry, throughout this study region;

2) identifiable urban and sub-urban physical needs and social needs of "survival" consequence likewise justify saving any and every outdoor recreation acre that can be saved or otherwise added to the slender existing stock.

Our environment for living "is not something that can be owned by individuals and exchanged in markets; traditionally, (in U. S. A.) we rely on the market mechanism to allocate scarce resources, but (that alone) cannot function properly to conserve and allocate environmental qualities". (R. F. F.)

The preservation of these irreproducible conditions depends ultimately on whether or not they are perceived as having positive value, i. e., survival significance.

"...Deteriorating conditions are now accompanied by rising expectations about environmental quality, and at the same time there is

a wide spread feeling that this country has the technology, the financial resources, and the administrative capacity for making improvements. What seems to be lacking is a way of putting the whole jigsaw puzzle together and then finding the will to do what is necessary." (p. 3, Annual Report for the Year 1969, Resources for the Future, Inc., Washington, D. C.)

Notable deficiencies in the 1970 Charles River watershed outdoor recreation environment are the current non-availability of some former simple enjoyments -- quiet walking or bicycling anywhere along the main river; protected and inviting spots for picnicking; overlook or outlook points along the river; a varied (and valued) landscape to look at; water clarity and water quality in the main river and some tributaries that would permit safe and enjoyable informal swimming and paddling by families with children.

Of course, in part, the deficiencies above-mentioned result from the pervasive brutalizations of these hurly-burly years, particularly the insensate diurnal surge of savage motorists in mindless competition with one another, hurtling their motor vehicles along the asphalt-burdened banks of the lower Charles. Take the automobiles away, perhaps by extended rapid transit, and it is faintly conceivable there could be an occasional return to genteel driving for pleasure on restricted and deliberately winding roadways -- now nearer, now farther from the watery ribbon --with stopping places, strolling places and picnic places on the river banks. Very likely this is an impossible dream. It would require also freedom from mugging, robbery, sex-hibitionism, and some relief by wider green-spaces from the ever-higher-towering urban buildings. However, as a dream for the principal scenic river, an industrially historic river, of the capitol city of Massachusetts, northeastern anchor of the megalopolis, it may be a dream worth holding.

By adding some 22,000 reserved acres, the Charles River environment could be significantly improved. Outdoor recreation opportunities could be increased some 80 percent in acreage, and be greatly re-inforced in long-term availability and accessibility by property additions by gift or purchase. Accordingly, the concluding chapter of this report recommends a 22,000 acre program, and indicates means of accomplishing it within the next five years. To lengthen the time-span for accomplishment would risk the loss to other non-recreation uses of vulnerable acres now on or near the river banks.

It would be ideal for outdoor recreation experiences to range from utmost wilderness to sophisticatedly urban enjoyments. In Massachusetts in the 1970's, especially in the long-settled Charles River

valley, utmost wilderness outdoor recreation is not available. However, a substantial immersion in "naturalness", and a sharply contrasting withdrawal from the sights, sounds, odors and associations of the intensively urban capitol-city-cluster of Massachusetts are currently available less than twenty miles from the state house dome. One may canoe silently on the winding, wooded Charles River in the second quarter of its length, between South Natick Dam and Medway Dam, or step aside to watch ducks feeding and herons fishing in the five-thousand acre Millis-Medfield marshes on that reach of river.

ACTION PROGRAM

26. ACTION FOR OUTDOOR RECREATION AND ENVIRONMENTAL CONSERVATION

The Charles River and its lands and tributaries are the single greatest recreational and environmental asset in the capital region of Massachusetts.

The preceding paragraphs outline a Charles River watershed need to add by 1985 some 22,000 acres of outdoor recreation and environmental conservation lands to the 1970 existing supply.

It is, therefore, suggested that, in addition to major natural valley storage lands (8,500 acres) recommended for protection by the Corps of Engineers, a State and local program, Federally assisted, be devoted to securing and protecting in perpetuity some 13,500 other acres along the banks of the Charles River main stem from end to end, including other wetlands, the headwaters slopes and selected portions of major tributaries.

Within a one-mile wide corridor along the Charles upstream of Watertown Dam and extending 1/2 mile each side of the river thread, there were in 1970 approximately 9,980 acres of existing dedicated public and semi-public lands, mainly for outdoor recreation and environmental preservation.

The recommendations demonstrate that prompt reservation of additional 22,000 acres in the watershed upstream of Watertown Dam would complete and secure the permanent protection and preservation of outdoor recreation opportunities and environmental asset conditions the whole length of the river.

The action program is geographically divided at South Natick Dam into two groups of action segments: five in the middle river between Watertown Dam and South Natick Dam; and eight in the upper river, between South Natick Dam and the headwaters slopes in Hopkinton.

Four levels of action responsibility are proposed: private municipal, State, and Federal. Actions at these levels are expected to be integrated and dovetailed by informal coordination through the Massachusetts Department of Natural Resources and the New England Division, U. S. Army Corps of Engineers.

A variety of preservation actions are proposed, beginning with individual river-bank and wetland owners, and proceeding up through municipal, district, county, State, and Federal actions to complete a continuous enlargement and protection of outdoor recreation opportunities along both banks of the Charles, from Watertown Dam to Echo Lake.

Acquisition of lands in fee simple and of interests less than the fee, but effective to keep the land open and not built upon, are the first objectives.

In the Charles River corridor, approximately 5,685 acres are proposed to be acquired in fee, and some 5,315 acres are proposed to be permanently "protected" totalling 11,000 acres which represents half of the above mentioned 22,000 acres.

There is ample legislated authorization for all the actions that need to be undertaken. One of the most recent and important statutes is Ch. 666 of 1969, the "Conservation Restrictions' Act". This statute makes easier and more permanent a range of private property actions to protect the value and enjoyment of land ownerships. Owners along any given reach of river could convey to one another or to their town or to a duly chartered Chapter 180 corporation of their choice, rights to keep open and not built upon forever, such river or wetland part(s) of their respective properties as they choose to designate, but retain full title and unfettered discretion to do as they choose with their own house-lot and road-fronting uplands. Such actions can be individually tailored by each landowner to his special situation.

The owner's counsel would advise as to possible municipal property tax and Federal income tax deduction consequences of such actions.

The means of protection begin with such right or restriction as a landowner may choose to give to his neighbors or to a local land trust or to the town or to the Trustees of Reservations or to the Massachusetts Audubon Society, or others. They range on through flood plain zoning (not permanent) to inland wetlands act designation by the Commissioner after notice and hearing, to acquisition in fee simple.

A private gift or grant of an "open space" restriction may keep the granted property private. It need not open the restricted area to the public. Even a commercial sale of rights to a public agency might validly include a limitation on rights of access to the property or interest in property so conveyed. A sale of all or part of a title could be made with reservation to the seller of exclusive life-time occupancy, or with other or different conditions.

The Metropolitan District Commission, a State agency, owns and administers continuous park-land ownerships or easements along the whole of both banks of the lower Charles, between Charles River Dam (Leverett Street, Boston) and Watertown Dam, upstream of Galen Street, Watertown. The MDC also has major but not continuous river-bank ownerships and easements between Watertown Dam and South Natick Dam. Accordingly, the recommendations in this chapter concern the whole of both banks between Watertown Dam and the headwaters slopes above Echo Lake Dam, on Honey Hill in Hopkinton.

The world-wide river study conventions of "left bank" and "right bank" are determined by standing at the headwaters (or any other point on the river) and looking downstream.

Fundamental to all actions suggested is the concept of local choice and direction among the various action possibilities. Land-owners, private trusts, non-profit corporations, and municipal officials have all been requested repeatedly to make their desires known. However, the need for protective action before 1975 is so great that where local private or municipal actions are not scheduled, it is recommended that State and/or Federal actions should be initiated, so that the whole of both banks of the Charles River become protected, together with major existing natural valley storage areas.

The guiding aim is to make available and actual, the outdoor recreation, fish-and-wildlife, flood reduction and scenic protection potentials in the whole of the Charles River watershed.

Direct Federal protective actions within the river corridor are recommended at several locations, including perhaps Beaver Pond, Bellingham; North Bellingham Dam; Millis-Medfield Marshes; Dedham Loop Marshes; and Leverett Street to Warren Avenue, Boston. Outside the corridor but within the valley there could be additional Federal protective actions, dove-tailed with State and/or municipal actions, at selected potential high run-off storage locations appropriate also for local recreation and environmental conservation.

The Massachusetts Water Resources Commission has issued regulatory orders for specific abatements of existing sources of pollution along the middle and upper Charles.

The Massachusetts Department of Natural Resources, with State and Federal funds is currently assisting seven Charles River municipalities in the acquisition of 816 acres of active and passive recreation and conservation lands at an estimated total outlay of \$2,274,140.

In the fiscal year 1966 through 1970, Charles River municipalities have been State and Federally aided in securing 824 acres, acquired at completed project costs of \$2,362,320 in the aggregate. Included in these 1966-1970 completed actions were \$503,500 of funds from the U. S. Land and Water Conservation Fund, administered by the U. S. Department of the Interior, Bureau of Outdoor Recreation.

The Massachusetts Department of Natural Resources encourages all 29 Charles River watershed municipalities and the MDC and others to initiate additional land-and-water-fund local acquisitions to achieve the recommendations of this report by 1975. Wherever local initiative is not exercised, it is recommended that State and/or Federal protection and acquisition measures shall be instituted, informally coordinated through the Massachusetts Department of Natural Resources.

27. SUMMARY OF RECOMMENDATIONS

The principal planning aims of the outdoor recreation and environmental conservation recommendations within the Charles River action corridor are repeated and summarized in approximate priority order as follows:

1. Protect all of both banks of the Charles River from end to end to establish in perpetuity a linear scenic and recreational waterway and adjoining landways for human enjoyments: canoeing, fishing, boating, bathing, bicycling, hiking, horseback riding, picnicking, sightseeing, bird-watching, and just plain grass-sitting, for examples.
2. To link up in perpetuity wherever feasible all existing public and semi-public lands on or near the Charles River banks. This will protect existing reserved lands and will reinforce and enlarge the outdoor recreation values of the entire reserved land system in the Charles River watershed.

3. By Charles River land (and water) acquisitions:

- a) permanently protect 11,000 acres or more of existing natural ponding areas, currently wetted at times of high rainfall or snowmelt: 7,000 of these acres along the Charles main stem and immediate tributaries, principally in the middle two quarters of the Charles River length; and 4,000 acres or more in off-main-stem locations, principally in the upper three-fourths of the Charles watershed;
- b) control and gradually eliminate polluted water inflows to the river;
- c) protect and improve the liveability and municipal taxable value of all properties throughout the Charles River watershed and environs;
- d) protect and improve the fish, bird and wildlife capabilities in the Charles River wetlands and related uplands;
- e) justify private, municipal and State development of a variety of "trails" -- interpretive of natural history; of colonial history; of industrial history; of educational history, all with recreation opportunities included;
- f) interconnect nodal points of recreation activity along the river, including places for passive enjoyment;
- g) create in the State capitol metropolis an unparalleled river recreation and landscape asset, unique in the northeastern United States and perhaps in the entire nation.

Permanent protection of major wetlands and related uplands along the Charles River and immediate tributaries is vital to flood detention and prevention in the middle and lower reaches of the river. Structural and non-structural actions to preserve forever the storm-water-storage capabilities in those areas also will enhance values for living and will protect the properties of a million or more current residents in the 29 principal Charles River watershed municipalities. This appears achievable by \$5 per person per year

average capital outlay for these purposes for five or six years. Ten cents per week per person (a five dollar bill each year) for fin, fur, feather and flood protection is a practicable outlay.

28. ACTION ACHIEVEMENT

Charles River wetlands and related uplands permanent preservation is proposed to be achieved by public regulatory protection of 5,315 acres and by public acquisition by gift or purchase of the whole fee of about 5,100 acres and by private (i. e., semi-public) acquisition of the fee or of effectual lesser property interest in some 560 acres of land within the Charles River action corridor.

The obviously wetted and wettable lands are likely to be effectually protectable for the ten years 1970 - 1980 by public police-power regulations:

- a) municipal flood-plain zoning;
- b) municipal and metropolitan water-supply sanitary controls;
- c) State inland wetlands designation;
- d) State review (Hatch Act) of individual filling or dredging proposals;
- e) Federal flood storage land acquisition and regulation measures.

Preservation of less wetted lowlands and related uplands will require \$27 million estimated capital outlays to complete governmental acquisition over the next five years, FY 1971 - 1975.

This estimate is based on the averaged land acquisition prices of the 816 acres currently under municipal purchase and sale agreements with State and Federal assistance through the Conservation Services Division of the Massachusetts Department of Natural Resources. The estimate is based also on the various averaged land acquisition prices, including all eligible costs of acquisition, paid for 824 acres acquired in 33 projects in 17 of the 29 Charles River municipalities, completed during the five years, FY 1966 - 1970.

Prices ranged from \$100 or less to \$9,000 per acre maximum, in completed projects as follows:

<u>Completed Projects</u>	<u>Combined Acres</u>	<u>Average Price Range/Acre</u>
13	286	\$ 100 - 1,000
8	133	2,000 - 2,500
2	127	3,167 - 3,750
3	173	7,900 - 8,800

As shown in the first two tabular lines on page 43, 21 completed projects embracing 419 acres cost \$2,500 or less per acre. Two projects covering 127 acres cost \$3,750 or less per acre. Excluded from the table were six projects completed in the city of Boston at a combined outlay of \$330,000 and a project in Brookline that not surprisingly cost in the range of \$30,000 per acre.

<u>Current Projects</u>	<u>Combined Acres</u>	<u>Average Price/Acre</u>
3	123	\$ 500 - 1,000
10	119	2,250 - 2,250
2	574	3,200 -10,750

From all the foregoing it is estimated that about half of the recommended 5,100 acres for public acquisition will be bought for \$2,500 an acre or less, i. e., about \$6,375.5 million capital outlay. Also, it is estimated that of the other acreage to be acquired, some 1,500 acres will cost \$3,000 - \$4,000 per acre, i. e., under \$6 million capital outlay, and the remainder acres will cost \$5,000 - \$10,000 per acre, that is about \$6 million capital outlay. Thus, a total 5,100 acre acquisition for about \$18.5 million capital outlay is envisaged. A fifty percent contingency allowance -- \$9 million -- is added for lapse of time, inflation, urban expansion and resulting escalation of land prices within the Charles River watershed during the years 1971 - 1975.

A \$27,500,000 Commonwealth of Massachusetts Charles River corridor land-and-water acquisition bond issue authorization is proposed to cover the whole cost of the recommended corridor action program exclusive of Federally acquired natural valley storage areas.

Federal and municipal cost sharing could reduce the State share of Charles River land preservation outlays to the range of \$5 million to \$9 million dollars. However, grants from the U. S. Land and Water Conservation Fund, allocated in advance, are paid only as reimbursements of completed projects, approved after completion. A single sufficient over-all State bond issue authorization is therefore suggested to assure completion of the entire program and to induce effective municipal and other participation.

Alternatively, a succession of \$5 million/year authorizations could be sought but this could prove costly in time, money, and effectiveness.

29. RELATION TO PRIOR PLANS

The Charles River corridor actions proposed are in harmony with, or not in conflict with, the proposals of all prior plans consulted, namely:

Massachusetts Section, U. S. Department of the Interior, Parks for America, 1964

Massachusetts Statewide Outdoor Recreation Plan Reports, 1966, 1957

Metropolitan Area Planning Council Open Space and Recreation Report., Vol. 3: the Mystic, Charles and Neponset Rivers, 1969

General Plan for the City of Boston, 1965

Individual City and Town Plans, 1956 - 1968 for each of the 28 cities and towns of the Charles, other than Boston

Parks and Recreation (or Open Space) Reports for cities and towns having separate reports.

Metropolitan Parks District Park, Reservation and Recreation Facilities Development Program, 1956. Edwards, Kelcy & Beck, Boston.

CHARLES RIVER WATERSHED PLAN

**PROPOSED
LAND
PRESERVATION ***

• INCLUDES LANDS EITHER
ACQUIRED OR PROTECTED



WATER RESOURCES INVESTIGATION

CHARLES RIVER STUDY

APPENDIX H

FLOOD MANAGEMENT PLAN FORMULATION

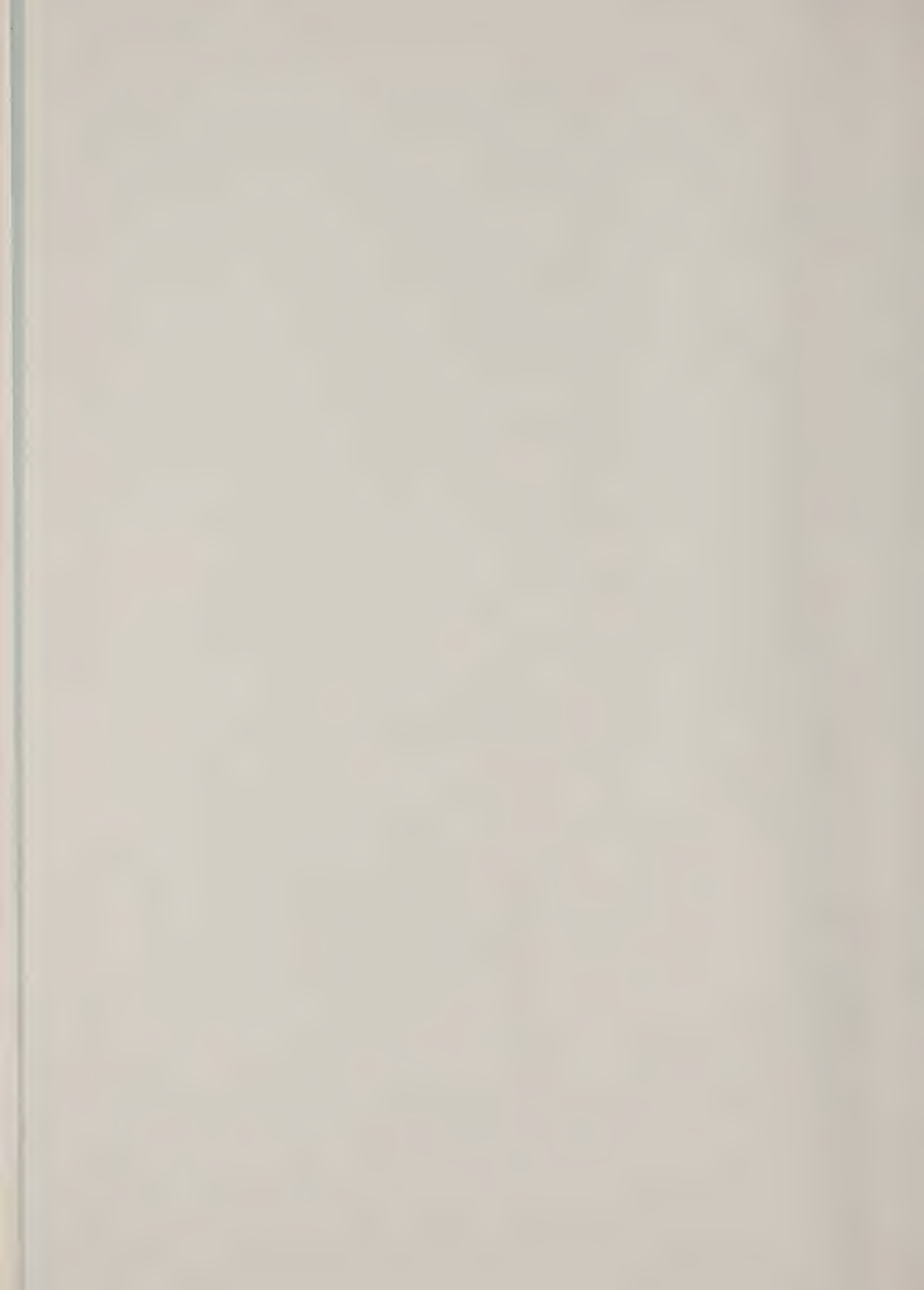
PREPARED BY

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASSACHUSETTS

DECEMBER 1971

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APPENDIX H

FLOOD MANAGEMENT

PLAN FORMULATION

1. INTRODUCTION

The Charles River Study is a Type III (Level C) study of survey scope which recognizes the need of all water related elements. The investigation was conducted in a comprehensive manner to assure that plans developed for flood management were fully coordinated with the needs of other resource uses. Accordingly, the needs of the watershed were inventoried, analyzed, and synthesized with the flood management plan forming the basic implementation vehicle for the over-all plan. The flood management plan formulated in this appendix is for the prevention of future flood damages and is enhanced by the watershed plan presented in the Main Report. Both plans are the results of a coordinated effort and present an optional organizational concept and balanced water resource plan for the watershed.

Early study findings were that present flood damage potential in the middle and upper watershed was minimal when compared with that of the densely urbanized lower basin. However, it was also clear that the rapidly urbanizing nature of the middle and upper watershed would shortly produce a flood potential similar to that of the lower. Investigation of possible flood management solutions included an analysis of all traditional flood reduction and control measures. These were found to be either inadequate to provide the management necessary to prevent serious future flooding or excessively adverse impact on the environment. For this reason, plan formulation gave major consideration to preservation of existing natural hydrologic conditions and to strengthening of over-all land-use controls. This approach satisfies both the increasing flood threat and the decreasing amount of land available for open space and recreation. Effective use of flood plain was evaluated by considering flood plain zoning regulation and wetlands legislation. Degrees of protection were analyzed to obtain a high order of protection for the least expense. The major areas capable of storing potential flood waters were located, mapped, tabulated, and analyzed. The plan recognizes further the environmental planning climate prevalent among many watershed residents and conservation groups who are proud of, and greatly concerned with "their" river. Any plan formulated must coincide with this environmental pride as well as be an economically justified water resource investment. On this basis, there is a great potential within the watershed for a model environmental river basin plan.

2. WATERSHED

An 8.6 mile long impoundment formed by the Charles River Dam located near the mouth of the river is known locally as the Charles River Basin. To avoid confusion, the entire area draining to the Charles River will be referred to throughout the report as the "Charles River Watershed".

The drainage area of the Charles River to the site of the proposed Warren Avenue Dam is 307 square miles, but the yield of the watershed is affected by early rights granted by the legislature to the proprietors of mills on Mother Brook in Dedham, to divert one-third of the flow of the Charles River through a canal to Mother Brook, and thence to the Neponset River. The watershed above this point of diversion is 198 square miles and hence, a flow equivalent to that from 66 square miles is diverted into Mother Brook reducing the effective watershed area at Warren Avenue to about 241 square miles.

The watershed is hour-glass in shape, 31 miles long, and about 15 miles wide in the lower and upper portions, narrowing to 6 miles in the central part. The countryside included is one of moderate slopes. Along the watershed divide, the higher summits seldom rise more than 300 or 400 feet above mean sea level (msl), and none reach 600 feet. As a result of the extensive natural valley storage, the lower main river is rather slow to respond to heavy flows from the upper watershed and the natural flows in the river are augmented from these areas. (See Plate No. 1.)

The Charles River watershed was subdivided into three parts, primarily because of the different hydraulic conditions which exist in the different sections of the river. The lower Charles River extends from Boston Harbor to Moody Street, Waltham, and traverses the highly urbanized section of the river and potential flood damage areas. The middle Charles River extends from Moody Street to the South Natick Dam in Natick and contains the established suburban communities. The upper Charles River from South Natick Dam to the headwaters in Hopkinton contains the section which changes in character from suburbia to a rural area.

PROBLEMS AND NEEDS

3. GENERAL

The environmental characteristics of the lower reach of the Charles River vary markedly from that of the middle and upper reaches which are a more suburban area. In the downstream portion, the watershed is heavily urbanized, nearly all paved over by development, and conducive to both tributary and main stream flash-flooding. The middle and upper regions are now experiencing a major transformation in character with extensive areas being urbanized in nearly all towns. To complicate matters, over the recent period of years of intensification, land development has affected river flows to the point where the river is drying up during low flow periods, and associated effects such as algae growth and duckweed, aggravated by pollution, are making the once beautiful stream unsightly and unproductive.

The greatest need is the development of a master plan for the watershed which will consider and establish water resource priorities as well as coordinate with State agencies their existing land-use programs for effective over-all objectives; to keep the river free of flooding both tidal and normal; to clean it up for an array of recreational pursuits; to keep it beautiful; and to enhance the social well-being of the densely-populated area which it serves.

4. EXISTING CONDITIONS

The Charles River, throughout the years has served, been abused, and in some instances, abandoned by the people. In recent years, interest has been generated in reclaiming "our" river. Recent improvements and usages along the Charles indicate new attitudes toward the values and resources of the river. Landscape architects have been retained by many communities and garden clubs to "dress up" sections of the river bank. Clean-up campaigns have been organized for many areas along the river. For example, a 700-acre area at the Needham-Dedham town line is planned as a nature area, and plans are under way to rebuild deteriorating dams.

a. Inland Wetlands Acts. Two major State laws currently deal with the protection of inland wetlands.

(1) "The Hatch Act", passed in 1965, attempts to control the dredging or filling of "any bank, flat marsh, meadow, or swamp

bordering on any inland waters". This control is administered by requiring a person who desires to make such alteration of the wetland to obtain a permit from the Massachusetts Department of Natural Resources. In filing his permit application, the applicant submits engineering plans and other relevant material indicating what it is he proposes to do with the wetlands. Two major problems have arisen in the operation of the Hatch Act. First, the burden of complying with the Act is on the developer. Second, the Hatch Act is not a statute which prohibits dredging and filling altogether. This statute gives a State agency a measure of control over dredge and fill projects in wetlands, but does not prevent such projects from being undertaken.

(2) "The Inland Wetlands Act", became effective in September 1968. It allows the Commissioner of Natural Resources, after a public hearing, and with the approval of the Board of Natural Resources, to place restrictions on the use of inland wetlands, in much the same way that local flood-plain zoning by-laws restrict the use of land which is subject to seasonal or periodic flooding. In this act the term "inland wetlands" shall mean any marsh, or swamp, bordering on inland waters, or any marsh or swamp subject to flooding by fresh water. The original intent of this Act was not to include the flood plain. It cannot be emphasized too strongly that the Inland Wetlands Act is not a substitute for local flood plain zoning. The law, which emerged from the Legislature, protects only those areas which are wet all year around, excluding, for example, river banks which may be under water in a spring flood, but relatively dry in summer and fall. Both laws, within their limited scope, serve a useful purpose. However, the Hatch Act and the Inland Wetlands Act were never intended to do the job of protecting the flood plain. If a town wishes to provide immediate protection to its wetlands, then adoption of a flood-plain by-law is the most meaningful, although temporary in nature, step it can take.

b. Flood-plain Zoning. Prior to 1958 no community within the Charles River watershed had established flood plain zoning. Since 1958 thirteen communities have enacted flood-plain zoning, or established conservancy districts. See Table No. 1.

The intent of flood-plain zoning is to protect life and property against near future flooding, and to contribute to protection against long term flooding. A flood plain zone is usually

TABLE 1
CHARLES RIVER STUDY
COMMUNITIES
WITH
FLOOD PLAIN ZONING OR CONSERVANCY ZONINGS

City or Town	Percent of Area in Charles R. Watershed	Frontage on Charles River		Frontage on Principal Tributaries			City or Town Flood Plain Zoned		Flood Plain Zoning Adopted	Conservancy Zoning Adopted
		Left Bank	Right Bank	Name	Left Bank	Right Bank	Area Acres	Elevations MSL.		
		Miles	Miles		Miles	Miles				
1. Ashland	4.3									
2. Arlington	6.3									
3. Bellingham	42.0	8.78	6.50	Hopping Brook	0.4	0.4				
				Beaver Brook	1.4	1.4				
4. Belmont	40.0									Yes
5. Boston	57.2	0.87	10.44	Muddy River	0.0	2.2				
6. Brookline	100.0			Muddy River	2.2	0.0				
7. Cambridge	64.6	6.13								
8. Dedham	66.9	6.17	6.87	Mother Brook			416	95	Yes	
				Diversion	0.1	0.1				
9. Dover	85.5		10.77	Trout Brook	2.0	2.0				Yes.
10. Foxboro	0.1									
11. Franklin	90.7		4.41	Shepard Brook	1.5	1.5	2,450	Varies	Yes	
				Mine Brook	5.0	5.0				
12. Holliston	99.5			Bogastow Brk	2.9	3.0				
				Chicken Brk	4.1	4.1				
				Hopping Brk	4.0	4.0				
13. Hopedale	18.8		1.77							
14. Hopkinton	10.2	0.26	0.26							
15. Lexington	29.5									
16. Lincoln	61.3			Stony Brook	3.0	3.0				Yes
17. Medfield	78.1		9.06	Stop River	2.0	2.0	1,415	125	Yes	Yes
18. Medway	100.0	5.78	1.17	Chicken Brk	3.3	3.3				
				Hopping Brk	2.2	2.2				
19. Mendon	1.6		0.91							
20. Milford	86.3	5.64	4.90	Lake Louisa						
				Outlet	0.3	0.3				
21. Millis	100.0	10.27	1.61	Bogastow Brk	4.5	4.5	1,280	125	Yes	
22. Natick	55.2	2.95	2.87	Davis Brook	2.0	2.0				
				Indian Brook	1.8	1.0				
23. Needham	100.0	11.93		Fuller Brook	1.5	1.5	672	Varies	Yes	
24. Newton	100.0		11.88							
25. Norfolk	99.7		2.04	Mill River	1.5	1.5	800	Varies	Yes	Yes
				Stop River	2.0	1.0				
26. Sherborn	83.4	4.65		Indian River	0.5	1.5	343	125	Yes	
				Farm Pond						
				Outlet	0.5	0.5				
				Sewall Brk	3.0	3.0				
				Bogastow Brk	0.1	0.0				
27. Somerville	33.9									
28. Walpole	1.0			Stop River	0.0	1.0			Yes	
29. Waltham	100.0	3.21	2.72	Stony Brk	2.0	0.0				
30. Watertown	86.3	4.47	0.70							
31. Wayland	2.6									
32. Wellesley	100.0	5.24		Waban Brk	0.5	0.5			Yes	Yes
				Fuller Brk	2.8	2.8				
33. Weston	91.0	2.59		Stony Brk	2.5	4.7				
34. Westwood	34.0		0.06							
35. Wrentham	43.4									

NOTES: Left or Right bank designations are moving from source to mouth.
Principal tributaries are limited to non-urban waterways
Areas of flood plain zoning are based on approximate measurements on USGS Maps 1" = 2,000

described as the area which lies below a specified elevation or sloped plane. This is in contrast to conservancy districts which are usually zones expressed in fixed distances from the center line of a stream. Emphasis in flood-plain zoning is on promoting proper use, rather than prohibiting use. Where natural high ground does not exist, building sites can be raised by filling, or structures can be built on "stilts". Contiguous low lands may be transformed into paved parking lots or paved open storage areas. Land which is flood-plain zoned today can be rezoned through variances in the future.

c. Publicly-Owned Land. The Metropolitan District Commission (MDC) has obtained ownership or control of nearly all of both banks of the Charles River between the Charles River Dam at Leverett Circle in Boston and the Watertown Dam just above Galen Street, Watertown. In addition, the Commission owns or controls the major portions of both banks of the Charles River between Watertown Dam and South Natick Dam. In total, the MDC today owns or controls 39.1 miles or 80.5 percent of the 48.6 miles (both banks) of the Charles River between the Boston Dam and Route 109 Dedham-Boston. The area of river frontage property and adjacent lands owned by the MDC totals approximately 3,100 acres.

Other publicly owned recreational land extending to the headwaters in Hopkinton totals some 14,000 acres. The largest holders of this total are the municipalities, which own 9,300 acres of forest, park, and recreational lands.

d. Mother Brook Diversion. This diversion was first made through an old canal which was excavated to connect the Charles River to the Neponset River in 1639. In 1831 an agreement was reached whereby it was decided that the mill owners on Mother Brook and the Neponset River should have the right to divert one-third of the flow of the Charles River, the other two-thirds would pass down to the mill owners on the Charles River. The Tileston and Hollingsworth Company, located on the Neponset River is still eligible for this diverted flow. The drainage area at the point of diversion is 198 square miles.

5. FLOODING

In recent years, the lower Charles has been subject to severe flooding. During the record flood of August 1955, damage amounted to an estimated \$5.5 million. A repetition of this flood would cause a \$12.4 million loss. This flooding is caused by the rapid run-off from the built-up areas of Cambridge, and Boston. Storm water

from upstream of Moody Street, Waltham, contributes little to lower Charles flooding. Peak water levels in the lower Charles Basin are reached four hours after a major rainfall, whereas peak flows from the upstream areas reach the basin three to five days later. This condition of little upstream influence on downstream flooding is primarily due to the natural valley storage areas of the upper watershed.

Throughout the middle and upper watershed, flood damage at the present time is not extensive. The relatively low flood damage experienced is attributed principally to the extensive marshes and swamps along the Charles and its principal tributaries upstream of the Silk Mill Dam in Newton.

Hydrologic studies have demonstrated the value of these wetlands and lakes. In the flood of August 1955, about 50,000 acre-feet of flow occurred after the peak discharge, most of this came from water stored in the wetlands and lakes. This is equivalent to about five inches of run-off from the drainage area of 184 square miles above the Charles River Village gage; which is approximately the same storage capacity as many of the Corps flood control reservoirs throughout New England.

Maximum flood flows are exceedingly low in the Charles when compared, for example, with the adjacent Blackstone River, which, by comparison, has little upstream natural storage. At a comparable point in the Blackstone, nearly 60 percent of the 1955 flood volume passed in two days. The entire flood had substantially passed in a week. At Charles River Village, only 10 percent passed in two days. It took a week to pass 50 percent of the flood and about a month for the total run-off to pass. During this 1955 flood, the peak flows reached 3,220 cfs at the gage. Flows in the Blackstone reached 16,900 cfs for a somewhat smaller drainage area of 139 square miles. That the peak flood flows from the upper Charles are extremely low is attributable to the natural valley storage afforded by the wetlands.

LOWER CHARLES PROPOSED PLAN

6. GENERAL

For purposes of study management, the Charles River watershed study was divided into two parts, the first reporting on the lower Charles, and the second covering the entire watershed. This was done mainly because of the entirely different hydraulic conditions which exist in the lower basin, in contrast to the remainder of the watershed. Consequently, by reporting initially on the lower area where the possibility of serious flooding exists, our findings and recommendations could be immediately implemented.

7. BASIN LEVEL CONTROL

Because of the congestion and built-up nature of the lower area, flooding occurs there rapidly after a heavy rainfall. The primary flood problem in the lower Charles River results from the high degree of urbanization, which causes intense run-off in a very short period of time and the fact that the harbor high tide is higher than the basin level. Aggravating the situation is the lack of control of the water level of the basin in which the run-off collects. The flooding problems of that portion of the watershed were discussed in depth in the Interim Report on flood control and navigation in the lower Charles River, which was completed in May 1968.

The report recommends construction of a multiple-Purpose dam in the Charles River in the vicinity of Warren Avenue, Boston. The new dam will include three navigation locks, a large pumping station and foundation for an overhead traffic viaduct. Separate sluicing facilities will discharge excess basin inflow to tidewater under normal conditions. Pumps would accomplish this need during a flood threat. Lowland and sewer flooding would be eliminated. A fish passage facility will be included to afford immediate access to habitat upstream to the Bleachery Dam at river mile 11.8 since the fishery at Watertown Dam will be reconstructed in 1972. Saltwater intrusion into the basin would be minimized. Preservation and enhancement of the highly-prized urban environment created by the lower basin is a prime engineering consideration.

MIDDLE AND UPPER CHARLES

FLOOD LOSS POTENTIAL

8. GENERAL

A study of the main stem of the Charles River above Watertown indicates a growing trend to encroachment on the flood plain especially by industrial and commercial interests. At the present time, most new development is taking place in areas not previously considered flood prone, with structures being erected on the higher portions of properties and the parking areas concomitant to suburban commercial development being placed at the lower elevations. Concentrations of industrial and commercial properties are located in Waltham, in Newton, at an office park in Wellesley, at an industrial center on the Newton-Needham line, at a shopping center in Dedham and in an industrial park on the Boston-Dedham line. Upstream of Dedham there is no industrial or commercial development as such. The difference in elevation between the parking lot and the first floor of the structure, in many cases, is only a couple of feet.

Over the years a certain amount of residential construction has been taking place along the river with concentration in the Waban section of Newton and in the Bridge Street area of Dedham and the rest scattered along both banks between Newton Lower Falls and South Natick. Up stream of South Natick only limited development has occurred in the flood plain.

The study finds that in addition to the development along the river proper, the entire upper Charles is becoming increasingly urbanized as an improving transportation network links the area to the core cities of Boston and Providence. While part of the increase is accounted for by the nationwide trend of movement from city to suburbia, overriding factors in the increase are the watershed's location, central to three major metropolises, Boston, Providence, and Worcester, and its supply of developable land. The natural valley storage areas are located in the center of the triangle formed by these three cities and therefore, are subject to the pressures of encroachment through filling and development.

9. URBANIZATION

The increasing urbanization of the Charles River watershed can be depicted in terms of population densities in the 18 communities upstream of the Route 9 bridge (as shown in Figure 1 and tabulated below) based on decennial census data in the watershed.

POPULATION DENSITIES

Population Area	Density/Square Mile			
	1940	1950	1960	1970
State	548.7	596.2	654.5	715.6
Watershed	347.0	422.9	586.5	760.1

Measured in terms of population, the lower Charles is the largest sub-region of the three. In 1965, over one million people resided here, representing 82.5 percent of the entire regional population. Since 1950, however, the population has declined by almost 200 thousand persons, or roughly 15 percent. At the same time, population in the middle and upper Charles has grown by 58.5 and 58.6 respectively.

The completion of two limited access expressways in the mid-1950's brought about a dramatic change in the watershed. Massachusetts Route 128, the so-called circumferential highway, running generally north to south through the lower part of the basin was opened to traffic in 1955; extending from the north shore of Massachusetts Bay in an arc around Boston at an average distance of 12 miles therefrom to the communities on the Bay's south shore, the highway gave ready and convenient access to all the major traffic arteries which radiate out of Boston to the north, west, and south. The opening of the Massachusetts Turnpike from the New York State line to Route 128 in 1956 gave the lower basin another major highway to the west and southwest. Industry and commerce moved quickly into the lower watershed to take advantage of the locational convenience; housing for the employees of the newcomers followed. Public rail transportation was available to a limited portion of the basin through the 1940's and early 1950's. With the opening of the then New Haven Railroad's "Station 128" in 1954, a new dimension was added to the service. Located adjacent to Route 128, and with access thereto, and possessed of a large parking lot with reasonable fees the station became very popular with both local commuters and long distance travelers to the south and west.

Late in the 1950's, the Metropolitan Transit (now the MBTA) opened its Riverside line providing semi-rapid transit from the Charles River in Newton to downtown Boston. Its Riverside terminal has a parking lot for 1,600 cars and ready access to Route 128.

The effects of all these improvements in the transportation system are to be seen in the sharp increases in density for the watershed in 1960 and 1970. What is more to be noted is that the population growth

was no longer limited to the three historic nodes in the lower watershed, indeed these had only moderate rates of growth; the growth in the 1960's was to the west and south of the older, more settled areas. The opening of the Massachusetts Turnpike's Boston Extension in the mid-1960's giving the lower basin rapid access to downtown Boston and its expressway system was one more factor in spreading the growth in the Route 128 portion of the watershed.

a. Growth Patterns. The influence of the transportation system on the watershed's development pattern is to be plainly seen. Early development was along the arc of Route 128 itself; as this tier of towns filled, the growth started in the adjoining areas to the south and west. The pattern for this growth was more random than the early growth, but generally it followed three regional secondary roads, Route 135, Route 16, and Route 109. These highways radiate out from Route 128 to the west and south. This gradual expansion trend was interrupted in the late 1960's with the construction of Interstate Route I-495, a limited access belt highway which roughly parallels Route 128 about 16 miles farther out from Boston. Even before the highway was completed in 1970, the Route 128 story was being re-enacted and the communities along this route through the headwaters of the Charles were the fast growing areas. This growth is projected to continue.

b. Effects of Urbanization. The continuing process of urbanization is causing a drastic change in the surface of the watershed, as roofs, pavements, and lawns with storm drainage systems replace the naturally vegetated rural acres of twenty years ago. As discussed in Appendix C, Hydrology and Hydraulics, these changes taking place in the watershed are having an accelerating effect on the run-off characteristics of the watershed. Precipitation drains to the waterways more quickly and in increasing amounts. The record flood of August 1955, which caused a peak flow of 3,220 cfs at Charles River Village gage was the result of 12 inches of rainfall over the basin. The flood peak occurred at the gage approximately 4 days after the rainfall ended. In March 1968, a rainfall of 5 inches over the basin produced a similar peak flow of 3,220 cfs at the same gage but with this flood the peak was reached 3 days after the end of the rainfall. The 1968 flood occurred during the spring snowmelt season when groundwater storage in swamps was high, thereby reducing their natural retention capacity. However, the August 1955 storm was preceded by a 2-inch rainfall only 5 days earlier which had raised antecedent conditions to above normal levels; therefore, though the two events are not directly comparable they do tend to demonstrate the fact that flood run-off in the basin is increasing due to urbanization which is taking place.

10. FUTURE CONDITIONS

As discussed in Appendix B, Economics, the elements of future growth are present in the watershed and the entire Charles River economic area is projected to grow at a rate which is slightly in excess of 1.0 percent annually for the next 50 years. The upper and middle sub-regions of the watershed, because of available land and an excellent transportation system, will substantially exceed the regional average. Densities in the sub-regions are projected to increase at a rate approximating recent historic trends for the next 20 years, and then level off as the areas begin to run out of usable land. Projected densities for the watershed above the Route 9 bridge are shown below.

Projected Densities, Charles River
Upper Sub-Regions

Year	1970	1980	2000	2020
Density	760.1	1059	1984	2198

Densities of this magnitude approach the U. S. Census Bureau definition of urban areas. With the watershed so urbanized, flooding can be an increasingly severe problem.

As previously noted, the August 1955 storm, and the March 1968 event, produced the same peak flow of 3,220 cfs at the Charles River gage, although in terms of rainfall frequency, the 1955 storm approximated a 100 year event, and the 1968 storm was more nearly a 25 year event.

Generally, because of the large amount of natural storage in the watershed, it has been rainfall amounts rather than intensity that have determined the magnitude of resulting floods in the Charles.

In the future, floods will be more frequent and greater in magnitude. Increased run-off, due to urbanization, will worsen the flood situation. Minor storms in 1980 will produce flows associated with moderate storms in 1970. Thus, the major storms of 1980 and 2000 will have much greater flood potential than similar storms under today's conditions.

a. Flood Damages. A recurrence of the record flood elevations of March 1968 would cause losses estimated at \$400,000 between Bemis Dam in Watertown and South Natick under today's conditions. About half of the loss would be residential. The balance would be commercial and light industrial interests. A stage one foot higher than the experienced 1968 stage would increase the loss to \$1 million, and at a stage of plus

two, the loss would be \$2 million. At a stage four feet higher than 1968, losses would exceed \$6 million. These are estimated direct losses; they do not reflect the drastic depreciation in property values for residential properties subject to frequent flooding nor the probable lowering of rental values in the industrial and office parks along the Charles.

The residential properties vary from units in the \$60 to \$80 thousand class in Waban through apartment buildings in Dedham and to \$20 to \$30 thousand single homes in the same community. A small trailer park also occupies the upper portion of the flood plain in Dedham. The bulk of the commercial properties are located in a large shopping center on the Boston-Dedham line with other concentrations in Newton Lower Falls, at an office park on the Wellesley-Newton line and at scattered locations in Dedham. Industrial properties subject to flooding, especially at plus stages are located in the Needham-Newton Industrial Center, a new industrial park in Newton and at scattered locations between Newton Lower Falls and Dedham. Some older industrial properties lying along the river banks in Waltham are also subject to plus stages of flooding.

b. Future Losses. Recent trends in flood loss potential indicate that in developed or partly developed areas losses tend to increase with time. This is especially true with industrial properties where the need to stay competitive means increasingly sophisticated plant, but it is also true for residential and commercial properties.

Part of the increase in flood loss potential is due to additions to existing properties, part is due to increased values of contents in structures such as color television replacing black and white sets, and in a land poor area, part is due to new construction occupying every available piece of land. All these items are related to the increasing wealth in the area. As noted in Appendix B, Economics, this wealth, expressed as personal income, is projected to increase approximately 6.5 times measured in constant 1958 dollars over the next 50 years. (Table B-2, page 38.) Current losses are projected to increase at a rate which is 50 percent of the increase in personal income. Recurring losses at various stages for future years are set forth as follows:

Recurring Losses at Various Flood Stages
Present and Projected in \$1,000's
(1970 Price Level)

Stage/Year	1970	1980	1990	2000
1968	400	500	620	820
1968 +1	1,000	1,230	1,550	2,040
1968 +2	2,000	2,450	3,100	4,070
1968 +3	3,500	4,300	5,430	7,120
1968 +4	6,000	7,350	9,310	12,210

The doubling of the flood loss potential in the thirty years 1970 to 2000 combined with the density projections for the same period make some form of controls imperative. While such controls could take the form of restrictive zoning by local (i. e. individual community) authorities the need for over-all control of the problem would call for a vast amount of coordination among the communities, coordinated efforts which it is hard to envision. A more realistic approach would be for some higher placed agency, State or Federal to handle the problem. This would almost certainly mean out-right purchase of the critical wetlands.

c. Valley Storage. As discussed in Appendix D, Hydrology and Hydraulics, flood problems in the Charles River watershed at the present time are minimized by a large amount of natural valley storage in swamps and other wetland areas in the watershed. Adding to the effectiveness of the wetland area are undersized culverts and bridge openings which in effect form flood water retarding structures of some of the watershed's roads. To negate to some degree the effects of urbanization, these wetlands and certain key waterway openings at the downstream end of wetlands must be maintained in their present condition. Discussed in Appendix D, Hydrology and Hydraulics, are the changes in flows and stages to be expected at key points in the lower basin in a recurrence of the record storms of August 1955 and March 1968 with the loss of varying percentages of valley storage.

d. Annual Losses. Recurring losses at various stages of flooding were combined with stage-frequency data to derive damage-frequency as a measure of annual losses. Natural annual losses in the reach of river between Charles River Village and Bemis Dam in Watertown amount to \$158,000 under current (1971) conditions.

Stage-frequency data were also developed for conditions to be expected with the loss of 10, 20, 30, and 40 percent of valley storage. These data combined with stage-loss data yielded annual losses to be expected with the loss of the valley storage. (See Appendix D.) Annual losses as developed are:

Annual Losses	
<u>Condition</u>	<u>Annual Loss</u>
Natural - 1971	\$158,000
With 10% loss of Storage	229,000
With 20% loss of Storage	414,000
With 30% loss of Storage	647,000
With 40% loss of Storage	957,000

e. Loss of Wetlands. In a study made by the Massachusetts Department of Natural Resources in 1967, it was determined that for the State as a whole, wetlands were being lost (i. e. developed) at a rate of 1 percent annually. Considering the present and projected pressures for land in the upper watershed, it is reasonable to assume that the rate of wetland loss is more than double the State-wide average. At this rate, over 50 percent of the wetlands will be gone in 20 years. Loss of these wetlands will mean a 30 percent loss of valley storage by 1990. This would mean annual losses in 1990 of \$640,000 under 1971 economic conditions. As previously discussed, losses are projected to increase over time at a rate which is 50 percent of the projected increase in personal income in the region. The increase in losses by 1990 brought back to present values using an interest rate of 5-3/8 percent amounts to an average annual equivalent increase of 34 percent.

PLANS CONSIDERED

11. FLOOD MANAGEMENT

a. General. In the past, flood damages in the middle and upper Charles River Watershed have not been major. There are buildings subject to flooding, but the total number and the monetary losses are relatively small. Although it would appear that at the present time no structural improvements are warranted, serious problems are inevitable unless strong corrective measures are sought to keep future flood losses to a minimum

The fact that the Charles River watershed does not have a serious flood problem is due to the significant modifying effect of the various swamps and marshes. These areas store potential flood water during high flows and gradually release the water without causing serious damage. The magnitude of the valley storage in the upper basin is reflected in the flood hydrographs recorded at the U. S. Geological Survey gaging station at Charles River Village. The maximum discharges occur about 4 days after the flood producing storm and it takes 3 to 4 weeks for the flow to return to normal. Hydrologic study of the Charles River demonstrated that natural storage in the wetlands of the watershed has a very important effect in modifying flood run-off and some lesser influence on augmenting low flows. Maximum floodflows in terms of cubic feet per square mile (csm) are exceedingly low in the Charles River when compared with the adjacent Blackstone River. The peak discharge at Charles River Village was only 17.5 csm compared with 121 csm experienced on the nearby Blackstone River at Northbridge. Therefore, preservation of the natural storage areas in the Charles River watershed is a major element of the watershed plan.

The attached tables and maps (Tables 2 and 3 and Maps 2 to 15) show 17 selected wetland areas suggested for preservation. These areas, located in 16 cities and towns, total about 8,500 acres. Only major wetlands exceeding 100 acres were included in this compilation. However, area "A" located on Beaver Brook, Waltham, Belmont and Lexington which initially exceeded the 100-acre criteria as measured from maps used in preliminary phases of the study, was found, upon field check, to have been filled and developed to a sizable extent and reduced to less than 100 acres. Therefore, it was omitted from consideration at that time. Subsequently, local interests have indicated an intense desire to have area "A" included in the natural valley storage plan. Accordingly, it will be included in future design stage studies.

b. Alternative Controls Considered. If the natural valley storage areas are not preserved, and urban development continues, many areas not previously susceptible to flooding will suffer flood damages in the near future. Preventing damages after an area is urbanized is difficult and costly. Methods of preventing flood damages through structural means include building retention reservoirs upstream of damage areas, constructing concrete walls, or earth dikes, straightening and channelizing portions of the stream, all of which would have adverse effects on the environment.

Early in the study, an analysis was made of potential flood storage reservoir sites. As expected, the investigated reservoir locations occurred at the natural valley storage areas since these are the areas which store the greatest amount of water for the least height of dam. Of the sites investigated, construction of a larger dam at the existing South Natick Dam offered the greatest capability. Eight inches of flood water run-off storage from the accumulated drainage area of 156 square miles could be retained by constructing a new dam twenty feet higher than the existing dam. This would necessitate taking land to elevation 140 mean sea level (msl), representing acquisition of 10,000 acres of land, and relocation of hundreds of improvements. The magnitude of this single-purpose flood control proposal can be appreciated by comparison of the 140 msl elevation with the elevation of the 1968 floodwater at Route 109, 10 miles upstream at the Medway-Millis town line, which was 121.7 msl. (See Charles River profile on Plates 2 and 3. In view of the high costs of this proposal, estimated at \$50 million, as compared to the damages prevented, and the adverse impact on surrounding communities and environment, this proposal was dropped from further consideration.

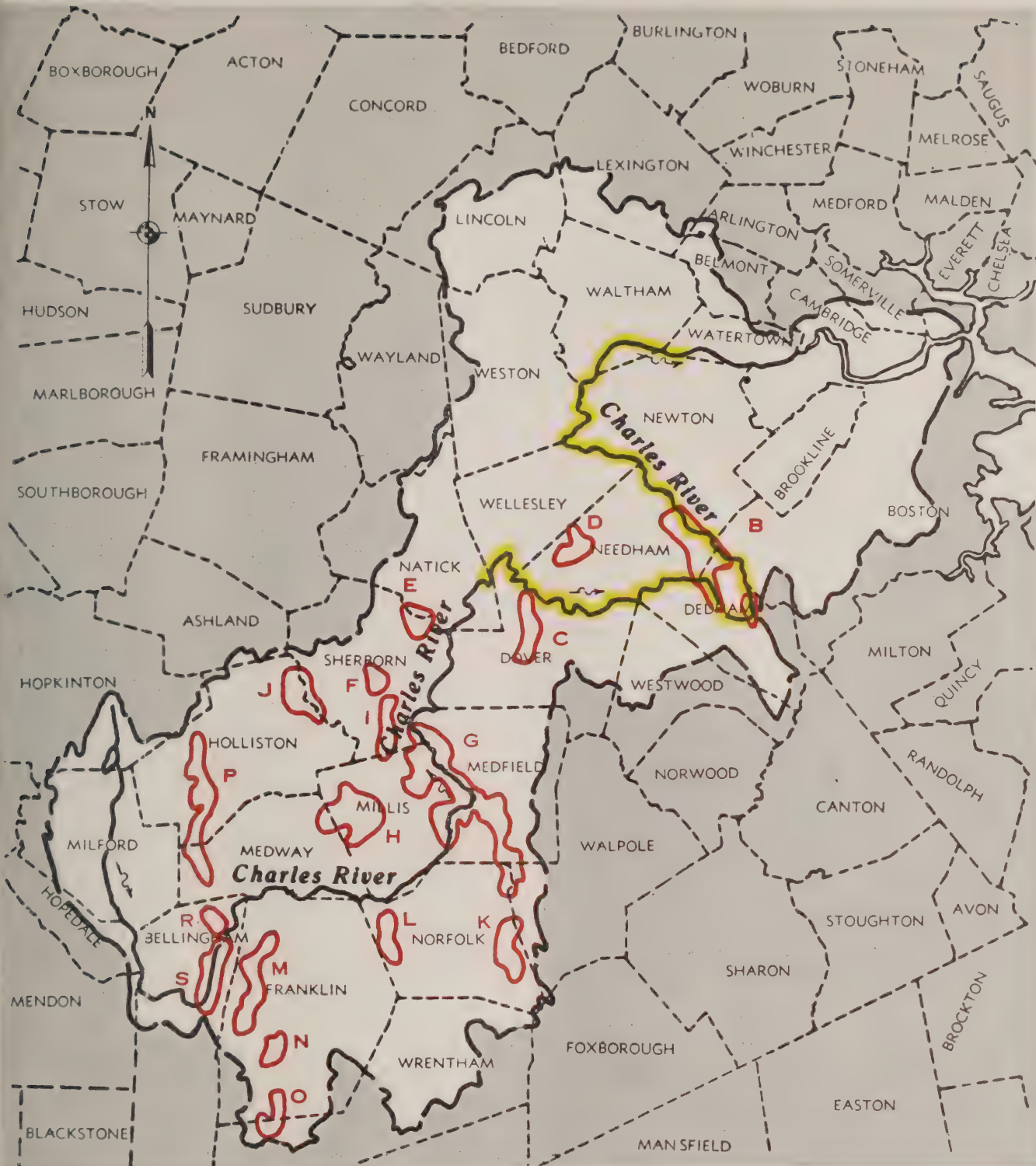
Two other potential main stem impoundment sites were also investigated. One located just upstream of the North Bellingham Dam, another

in the vicinity of the Forest Road Bridge in Millis (river mile 54.5). Project purposes considered included flood control, low flow augmentation, and recreation. These sites were eliminated from further consideration due to insufficient benefits and the adverse effects to the water quality due to the relatively shallow pools created by these impoundments.

Tributary multiple-purpose reservoirs were studied by the Soil Conservation Service of the Department of Agriculture. Their primary investigations concentrated on the upstream portion of the watershed, extending from South Natick Dam upstream to the southwesterly boundary of the watershed, an area of about 151 square miles. The Soil Conservation Service determined the extent of present and projected damages from floodwater, sediment, inadequate drainage, and erosion in the upstream area. Concurrently, sites were inventoried, screened, and analyzed as potential water impoundments for a balanced multiple-purpose water resources plan. The potentials of these sites include camping, fishing, boating, swimming and picnicking. Forty-seven such areas were investigated resulting in the conclusion that the Charles watershed is not generally favored with good dam or reservoir sites. The abutments tend to be porous, or real estate costs are prohibitive for large impoundments. See Appendix F, Tributary Watersheds, for more detail.

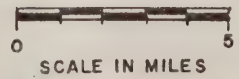
Since retaining the potential damaging flood water by means of new reservoir developments is impractical, the alternative structural method would be to have the flood waters pass by a protected potential damage area. This would entail diking and walling sections of the river adjacent to high damage areas. Other sections of the river would require dredging and concrete lining to increase flow. Traditionally, damaging flood waters cause serious monetary loss and the reaction to the problem is to design and construct protective works rather than to provide preventive measures.

Local protection projects were studied for areas susceptible to near future flood problems. Layouts were made which included channel and rock excavation, concrete walls or earth dikes, and rock slope protection. Within the limits of the local protection project, existing dams would have to be removed and bridges rebuilt. An estimate for local protection and replacement of 11 bridges is \$30 million for a 10-mile length of the river. Throughout the construction periods, there would be much disruption of traffic, hardship to local merchants, and inconvenience to the public. When completed, the new structures would replace the placid river and its environment. The cost of providing this type of protection is extremely high and disruptive, therefore this alternative was abandoned.



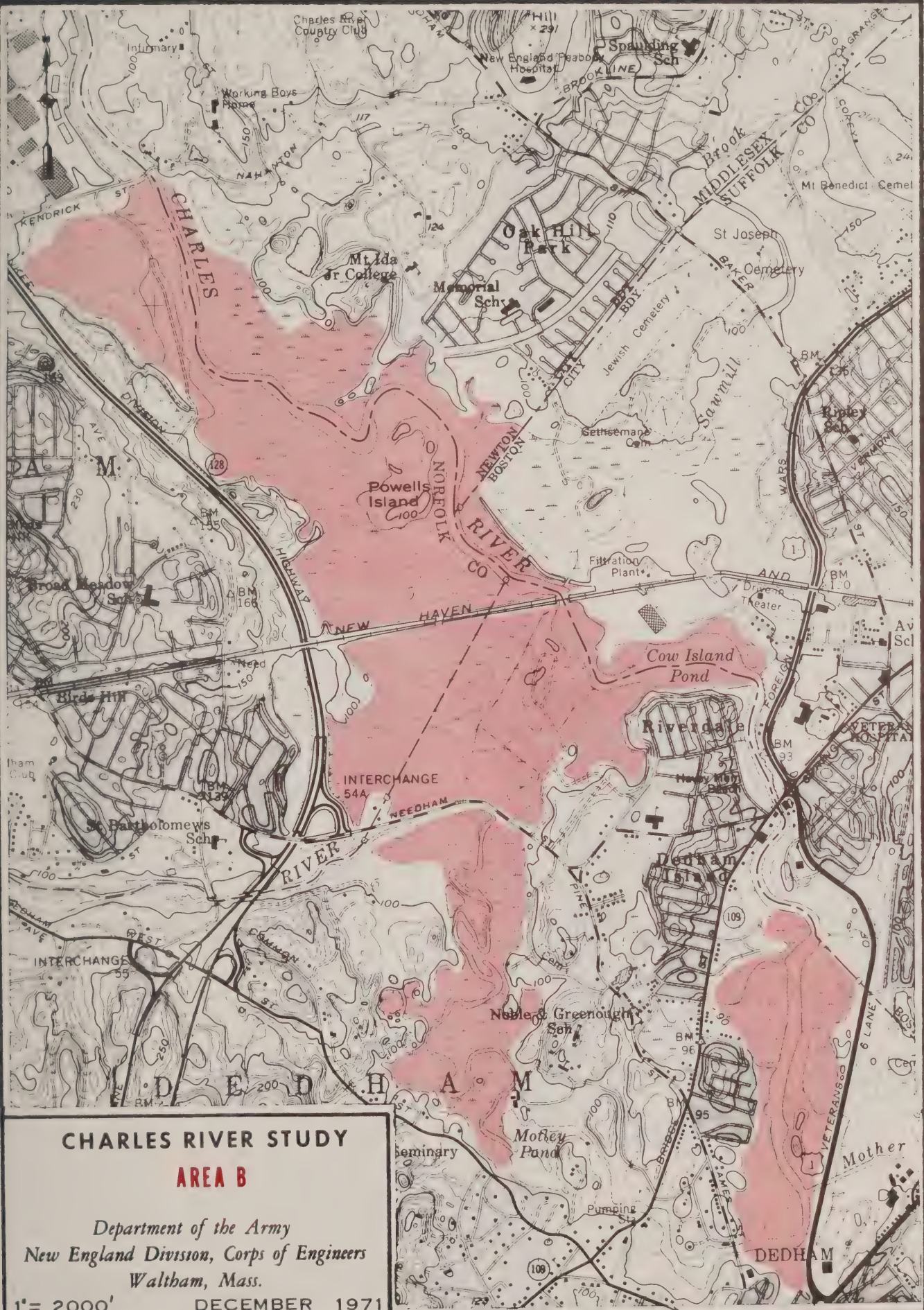
CHARLES RIVER WATERSHED

NEW ENGLAND DIVISION, CORPS OF ENGINEERS



NATURAL VALLEY STORAGE AREAS
AREA OF HIGH LOSS POTENTIAL

FIGURE H-2

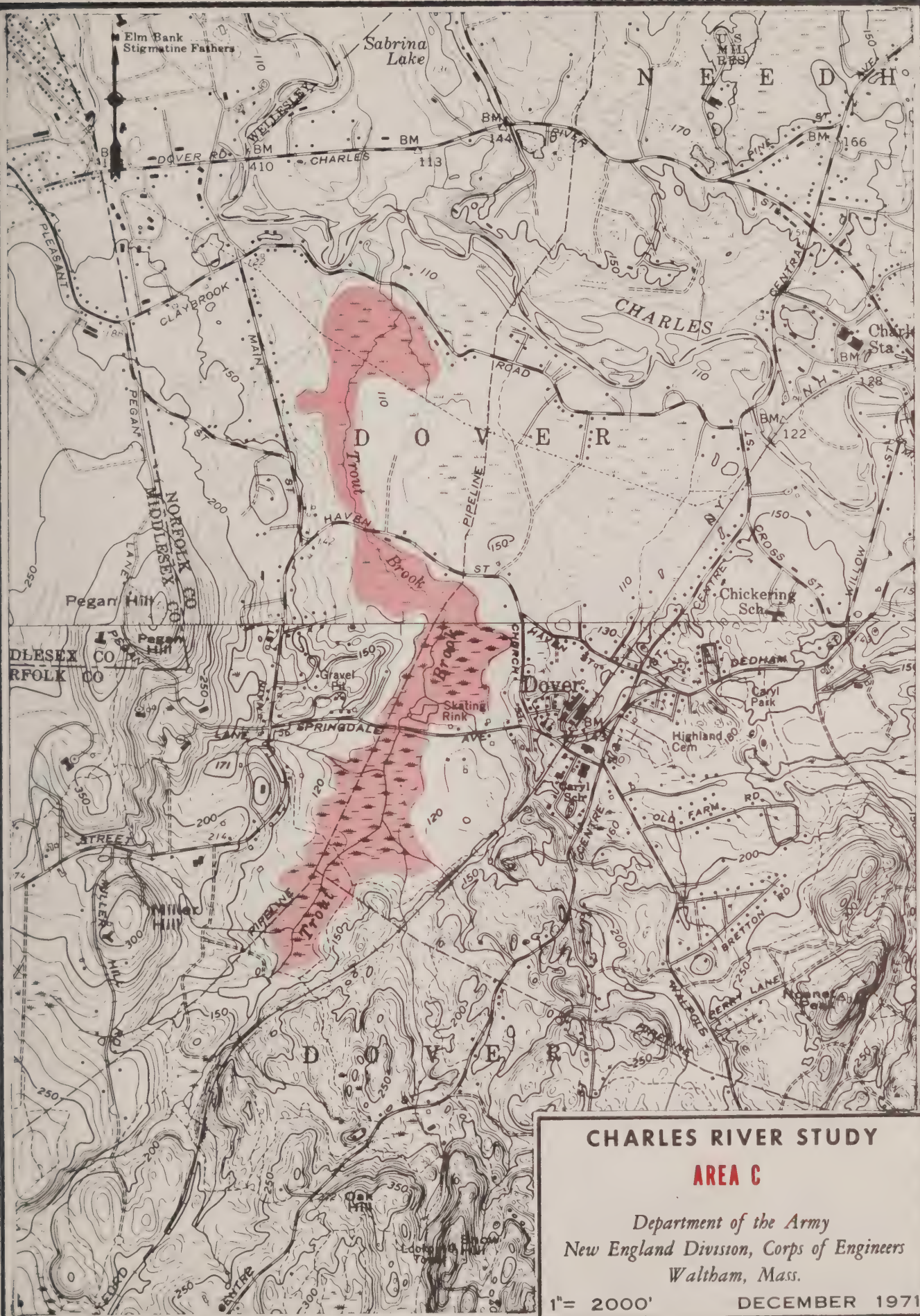


CHARLES RIVER STUDY
AREA B

Department of the Army
New England Division, Corps of Engineers
Waltham, Mass.

1" = 2000' DECEMBER 1971

FIGURE H-3





CHARLES RIVER STUDY

AREA D

*Department of the Army
New England Division, Corps of Engineers
Waltham, Mass.*

1"= 2000' DECEMBER 1971

FIGURE H-5



CHARLES RIVER STUDY

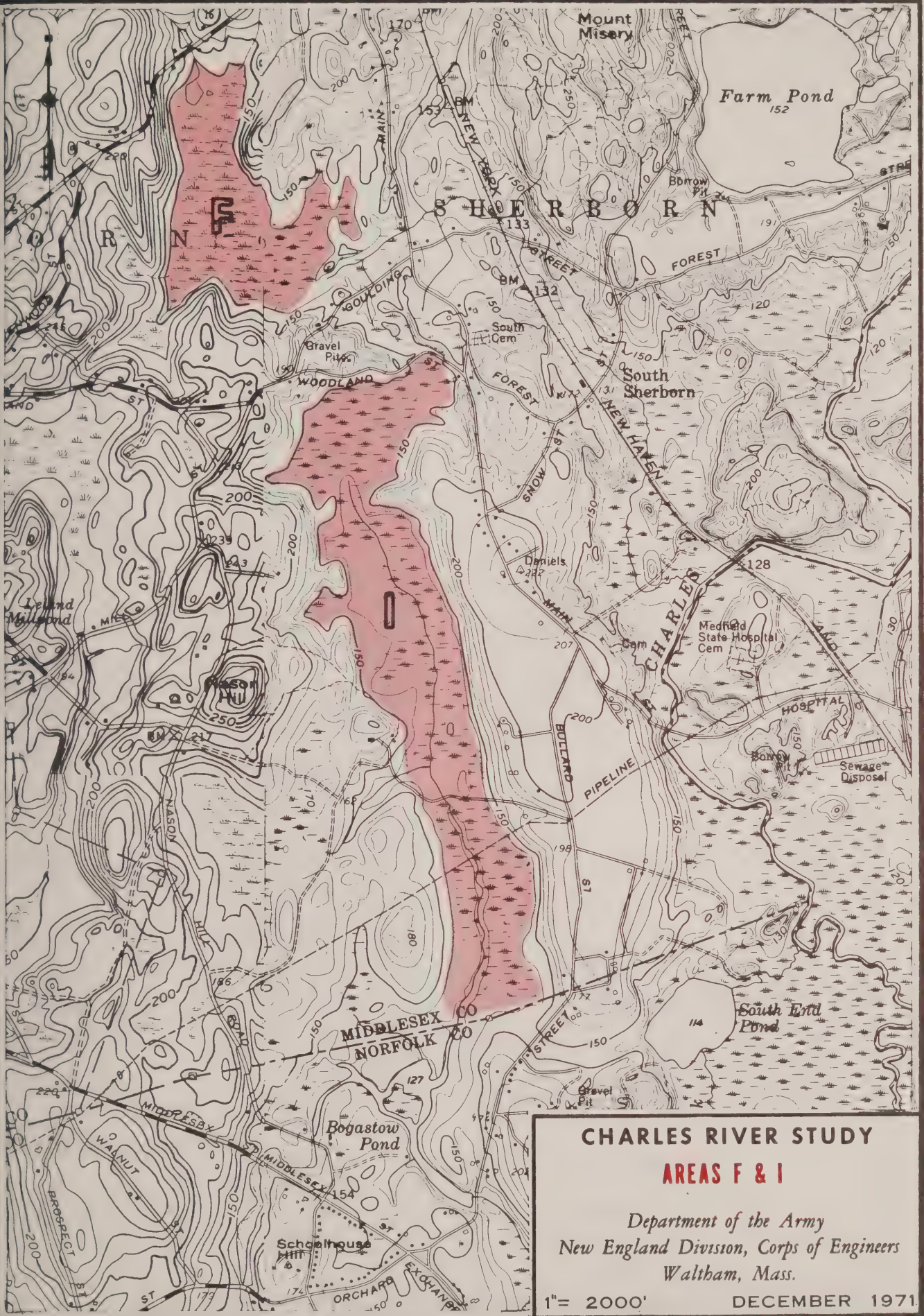
AREA E

Department of the Army
New England Division, Corps of Engineers
Waltham, Mass.

1" = 2000'

DECEMBER 1971

FIGURE H-6



CHARLES RIVER STUDY

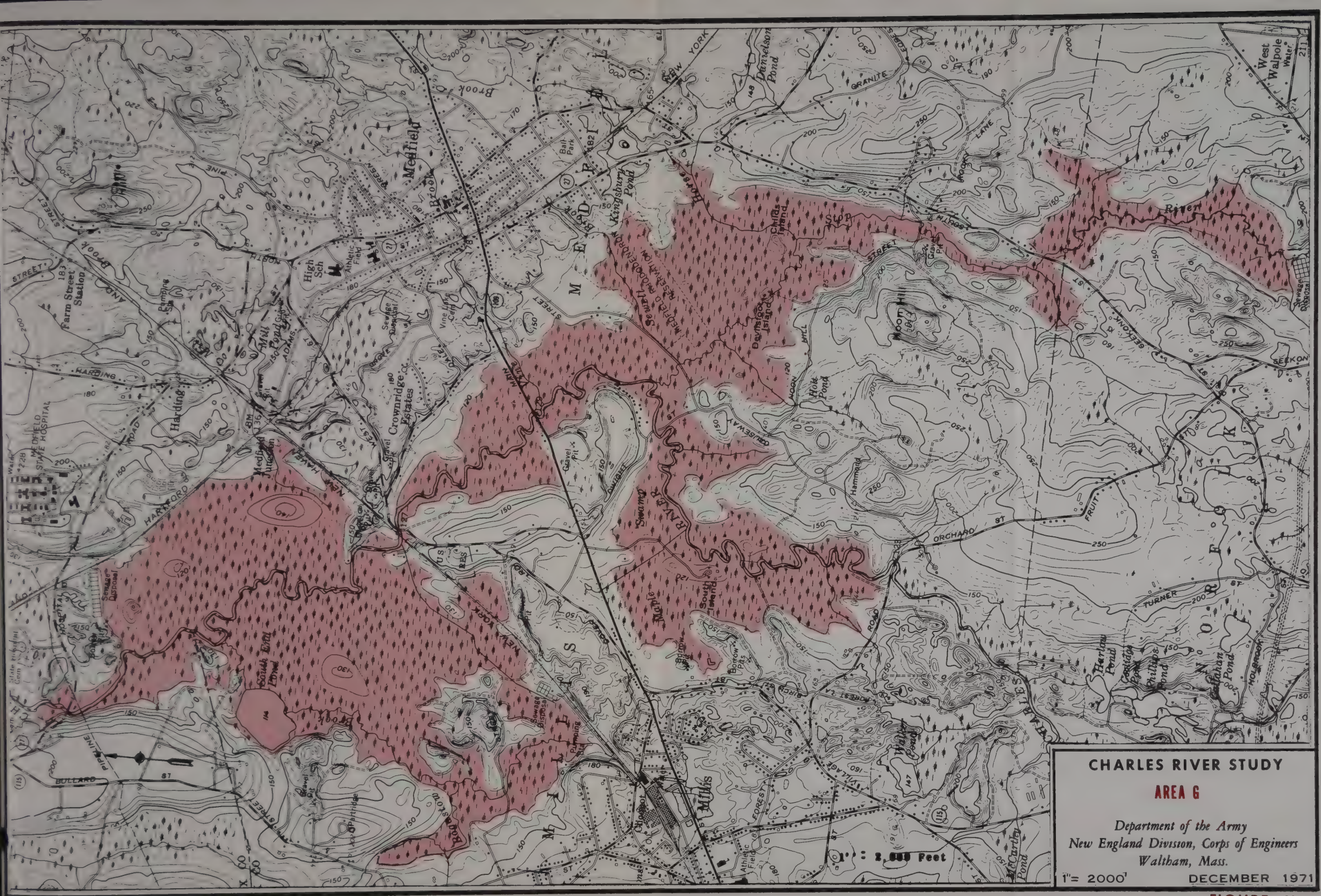
AREAS F & I

Department of the Army
New England Division, Corps of Engineers
Waltham, Mass.

1" = 2000'

DECEMBER 1971

FIGURE H-7



CHARLES RIVER STUDY

AREA G

Department of the Army
New England Division, Corps of Engineers
Waltham, Mass.

1" = 2000'

DECEMBER 1971



FIGURE H-9



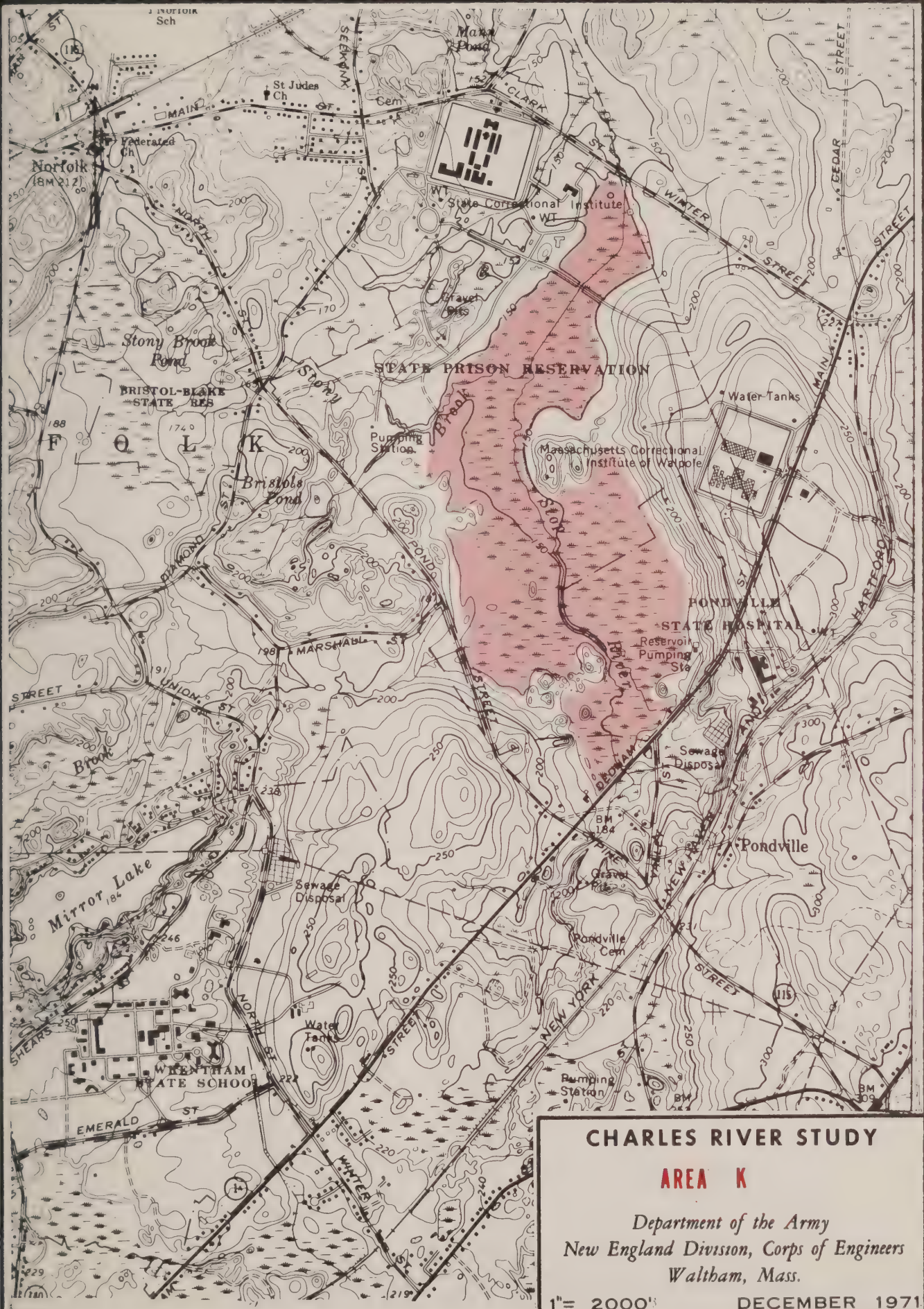
CHARLES RIVER STUDY

AREA J

Department of the Army
New England Division, Corps of Engineers
Waltham, Mass.

1" = 2000'

DECEMBER 1971



CHARLES RIVER STUDY

AREA K

Department of the Army
 New England Division, Corps of Engineers
 Waltham, Mass.

1" = 2000'

DECEMBER 1971

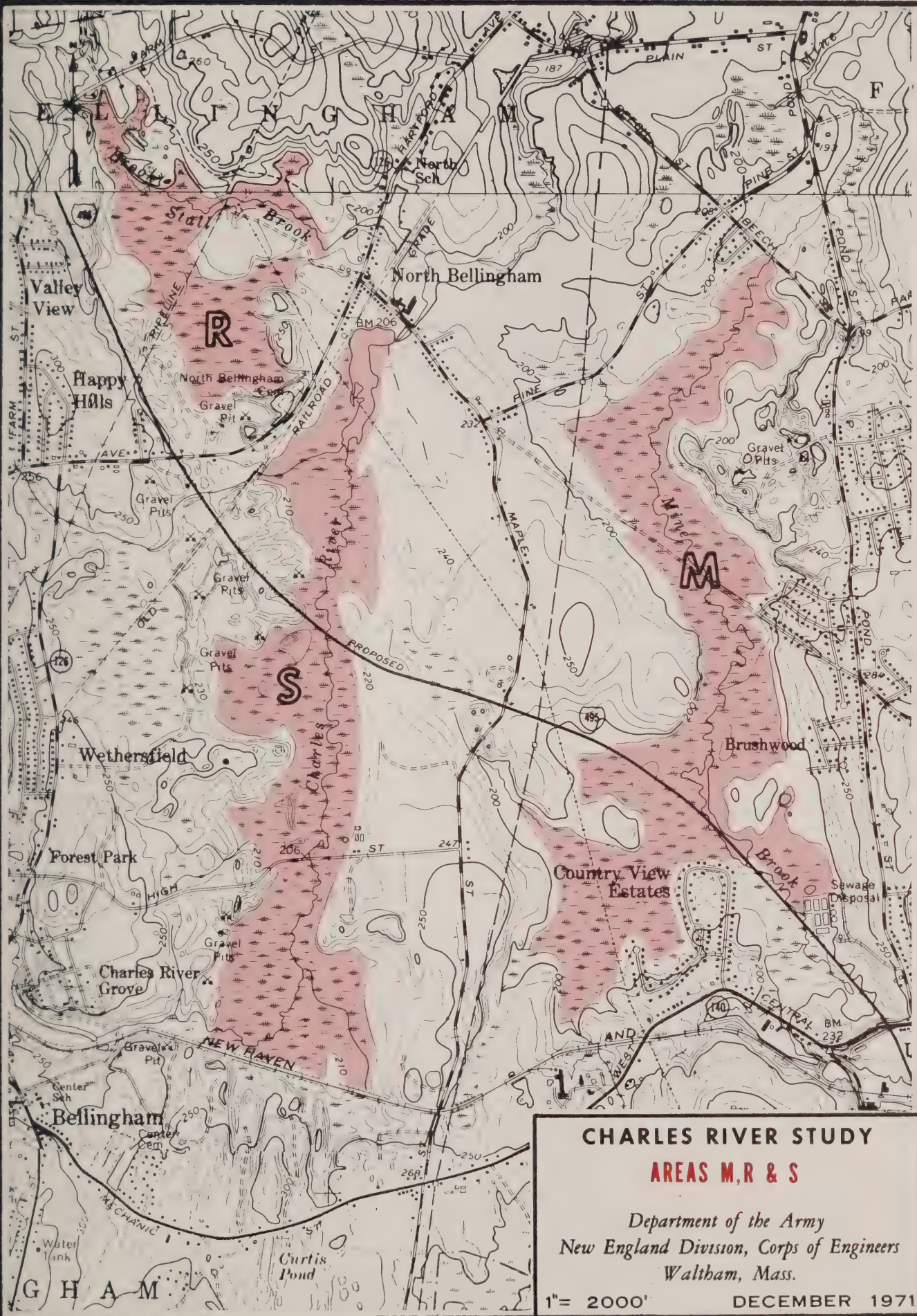


CHARLES RIVER STUDY
AREA I

Department of the Army
New England Division, Corps of Engineers
Waltham, Mass.

1" = 2000' DECEMBER 1971

FIGURE H-12



CHARLES RIVER STUDY

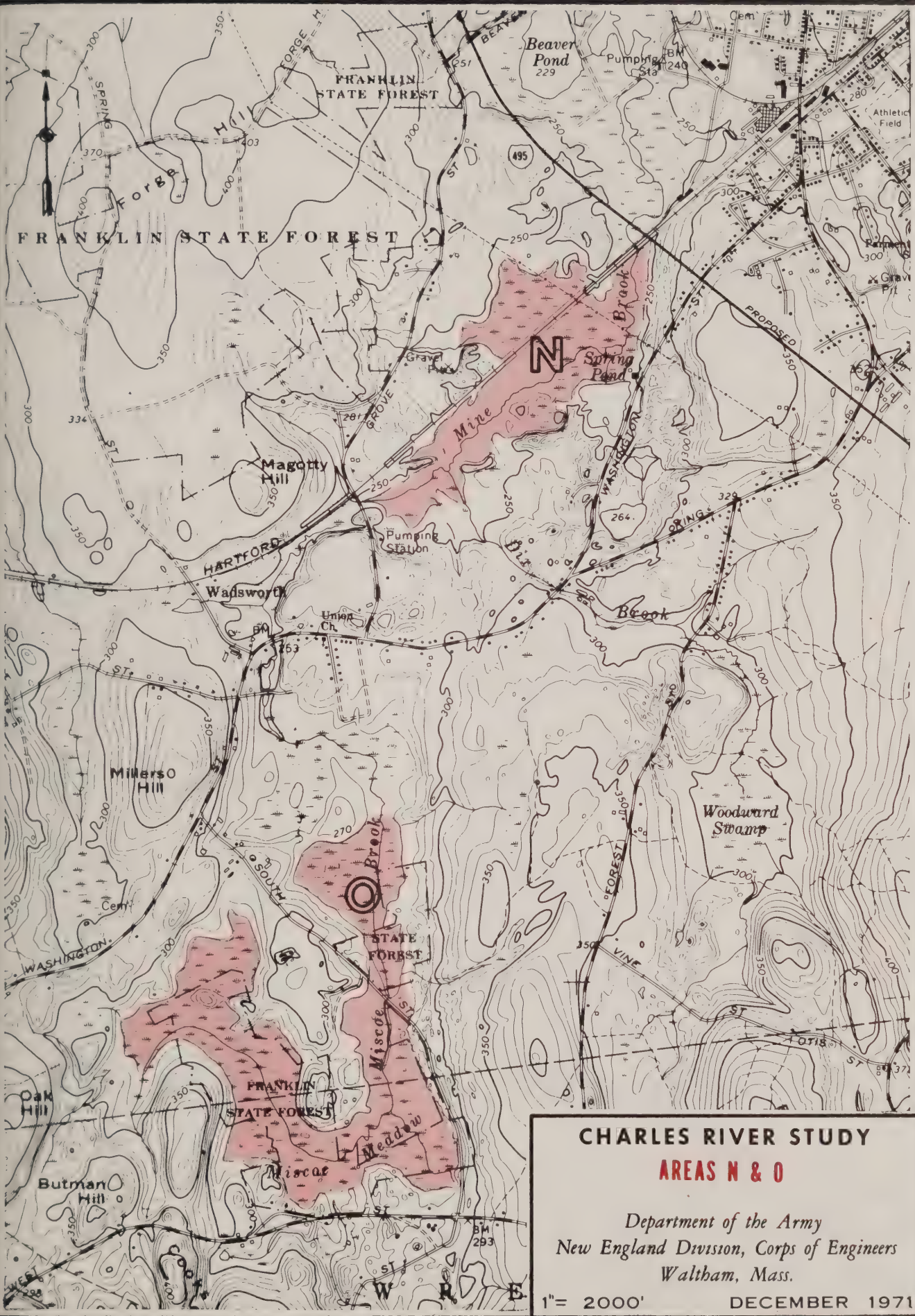
AREAS M, R & S

Department of the Army
New England Division, Corps of Engineers
Waltham, Mass.

1" = 2000'

DECEMBER 1971

FIGURE H-13

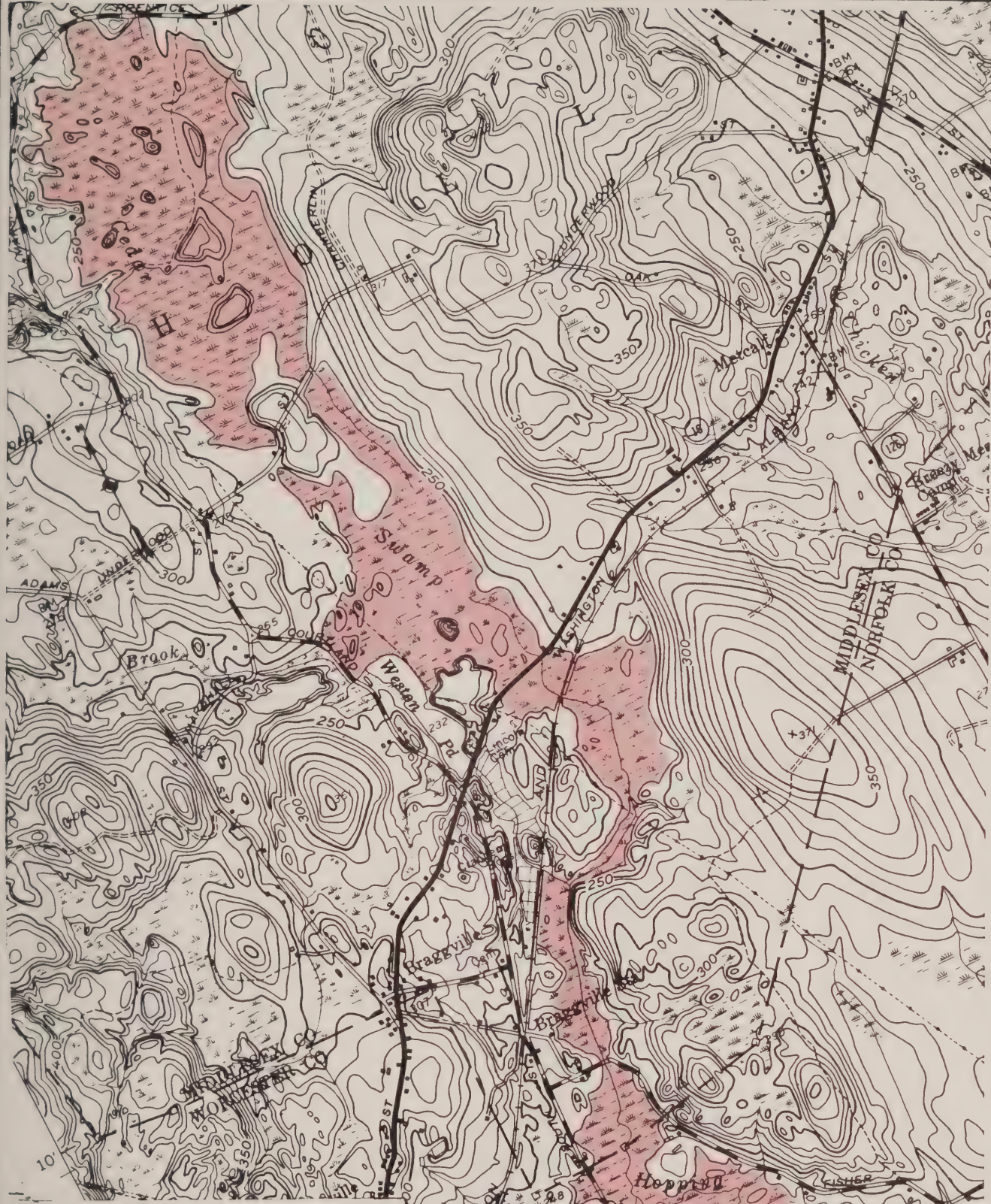


CHARLES RIVER STUDY
AREAS N & O

Department of the Army
New England Division, Corps of Engineers
Waltham, Mass.

1" = 2000' DECEMBER 1971

FIGURE H-14



CHARLES RIVER STUDY

AREA P

Department of the Army
New England Division, Corps of Engineers
Waltham, Mass.

1" = 2000'

DECEMBER 1971

FIGURE H-15

TABLE NO. 2

NATURAL VALLEY STORAGE AREAS

<u>Designation</u>	<u>Stream</u>	<u>Acreage</u>	<u>Communities</u>
B	Charles River	1,029	Needham-Newton-Boston-Dedham
C	Trout Brook	250	Dover
D	Fuller Brook	284	Needham
E	Indian Brook	234	Natick-Sherborn
F	Sewall Brook	118	Sherborn
G	Charles & Stop Rivers	2,340	Norfolk-Sherborn-Medfield-Millis
H	Bogastow Brook	907	Medway-Millis
I	Tributary to Bogastow Brook	280	Sherborn
J	Dopping Brook	130	Holliston-Sherborn
K	Stop River	395	Norfolk
L	Mill River	360	Norfolk
M	Mine Brook	395	Franklin
N	Mine Brook	150	Franklin
O	Miscoe Brook	266	Franklin-Wrentham
P	Hopping Brook	704	Holliston-Medway
R	Stall Brook	180	Bellingham
S	Charles River	400	Bellingham

TABLE 3

NATURAL VALLEY STORAGE AREAS
RECOMMENDED FOR PRESERVATION ACREAGE
IN TOWNS AND CITIES

<u>Town/City</u>	<u>Wetland Acreage</u> (acres)
Millis	1,797
Medfield	1,177
Norfolk	827
Franklin	731
Holliston	694
Needham	684
Sherborn	674
Bellingham	580
Dedham	500
Dover	250
Medway	180
Newton	100
Wrentham	80
Walpole	75
Natick	44
Boston	29

Evacuation from, and relocation of, structures in the flood prone areas was studied. These methods proved to be more costly than the local protection projects required to protect existing buildings.

c. Protection Through Preservation. Spring freshets are stored in the wetlands as are the potential damaging flood waters. A land acquisition plan is essential if the beauty and natural environmental Character of this section of the river is to be preserved to please future generations in the eastern Massachusetts metropolitan area. Without restrictions, these wetlands, subject to urban expansion by upstream communities, may well produce a setting similar to lower Charles River cities which represent a conglomerate of roads, driveways, parking lots and rooftops.

On a State-wide scale, Massachusetts is losing its wetlands at a rate of 1 percent per year. Certain communities near Boston have been estimated as having lost up to 50 percent of their wetlands since 1951. If nothing is done to halt this trend, wetlands in the Charles River valley will disappear. The area between Route 128 and the recently opened Route 495 is particularly vulnerable to loss of wetlands. Wetlands will be filled and river banks lined in search for buildable space. Unlike a true marsh, these "wet meadows" can be easily drained, filled, and developed. With a loss of wetland storage, an increase of run-off will occur, with a corresponding increase of flood height.

The areas designated, presently, are not prime land for development, and their value and tax producing value is low. In town planning reports, consideration has been given to setting aside the river areas and marshes through flood plain zoning, establishing conservancy districts or through town ownership of land. Thus the municipalities have shown an awareness of the need for retaining the wetlands. All natural valley storage areas have been considered by town planners or their consultants for flood plain zones, conservancy districts, or open space areas for community use. Many of the areas are presently designated in one of these categories. By enacting comprehensive land use plans and zoning ordinances, communities can guide and channel development. Preservation of the swamps and marshlands is needed not only because they are beneficial in controlling floods, but also because they are of considerable value for fish, wildlife, and passive recreation.

12. SELECTED FLOOD MANAGEMENT PLAN

a. General. The plan provides environmental protection by retaining nature's flood control retention areas - the wetlands of the Charles. Swamplands have commonly been regarded as wastelands, but these areas act as retention basins, and, if lost, serious flooding will be inevitable. Building structures to prevent flood damages are expensive. Returning a developed wetland to its natural state is impractical, even if the process were not irreversible. The wetlands, in addition to providing flood protection benefits, fulfill a passive recreation need through the reserved open space area. The wetlands are slow to release the large quantity of stored water thereby recharging the groundwater. The natural habitat for fish and wildlife is also protected. Protecting the wetlands to maintain a basic natural function is proposed, i. e., to naturally store water during high flows and to enhance the environment through a balanced ecology.

b. Determination of Project System. Hydrology studies were made to determine the effect the wetlands of the Charles have on modifying floods. The March 1968 flood occurred during the completion of the lower Charles River Interim Report, demonstrating the value of flood water retention of natural valley storage and delineated the extent of inundation in the major wetland areas. The total amount of swamps, marshes, and wet meadows in the watershed is approximately 20,000 acres ranging in size from less than an acre to 2,300 acres. These numerous wetlands have a varying regional effect and some criteria was needed for Federal involvement. The extent and location of the critical areas were studied, and 100 acres were selected as the minimum size being practical for Federal purchase, operation, and administration. As the area becomes smaller, the depth is less and the storage per unit area becomes proportionately less. Hydrologically, approximately 10,000 acres, about half the total wetlands, located in 19 areas, were selected as having major flood water retention capabilities. The critical areas are either located adjacent to the Charles River or on one of the larger tributaries. Not all areas containing more than 100 acres were included, where adjacent primary storage areas provided adequate control.

Geographically, the natural valley storage areas are separate units uniformly distributed throughout the watershed. However, hydraulically, all the areas act as one integrated system. The natural separation of the area has hydraulic merit for the concentration of flood flows from the watershed are greatly retarded and desynchronized by the sequential routing of flows from one storage area to another, in contrast to the rapid travel time via translation of flows on a continuous large body of water.

No attempt was made to analyze the economics of various areas individually, for each area is considered an integral link in the over-all hydraulic chain and an integral part of the over-all system. If one of the areas was excluded and its storage capacity eventually lost, it could have an over-all detrimental effect on nature's unique system of storage areas. For example, the loss of one storage might overtax the next downstream storage area causing increased periphery flooding. The only practical solution would then be improved drainage in that storage area, voiding its storage effectiveness, resulting in magnification and movement of the problem progressively downstream.

The natural valley storage areas, as a system, have provided reasonable control for all floods of record and would provide major modifications to events as great as the Standard Project Flood. The areas selected are considered primary and the minimum number required to provide an over-all practical system.

Discussed in Appendix D, Hydrology and Hydraulics, is the hydrograph analysis for determining the storage contained in wetlands and lakes of the watershed. Approximately 50,000 acre-feet, equivalent to about 5" of run-off from the drainage area of 184 square miles, were stored above the gage at Charles River Village during the 1955 flood. It is estimated that the designated natural valley storage areas upstream of the gage control 75 percent of the total wetland and lake storage and the total 17 natural valley storage areas located both upstream and downstream of the gage control about 42,000 acre feet.

During the 1968 flood the wetlands of the Charles were under constant surveillance by engineers to determine the effectiveness of flood water retention. Since the 1968 flood was similar in magnitude to the flood of record, and fairly recent, the elevation to which the lands were inundated by this flood was studied and the system of wetland storage analyzed. The elevation of the 1968 flood will be used as a "design" height of acquisition in the designated valley storage areas.

To optimize the unit cost of acquisition each area was field checked further by a real estate appraiser and an engineer to determine the practicality and economic feasibility of buying these areas. Town master plans were reviewed to determine if the selective areas were complementary to the thinking of community planners. Subsequently, the initial 19 locations were reduced to 17 areas containing about 8,500 acres. This reduction of two areas was due to recent development in those areas and their size being reduced to less than 100 acres and flood water retention capacity being limited.

c. Wetlands Outside the Project. The Charles River watershed contains approximately 20,000 acres of wetland. Of this total, about 8,500 acres of wetland were designated as having significant flood water retention capabilities and were included in the multiple resource management plan in the project system. Federal acquisition will effectively protect these properties, but the fate of the remaining over 11,000 additional acres of natural storage is also important to flood control in the middle and upper watershed. This land is outside of both the Corps' flood management plan and the Department of Natural Resources Corridor Plan as described in Appendix G, Outdoor Recreation and Environmental Conservation. It consists of smaller wetland areas that individually have less significant regional effect on flood run-off. The alarming development trends discussed earlier apply equally to these lands, and some manner of land use controls are imperative. Once a field is subdivided, a swamp filled, a river and pond encroached upon, or a forest cut, the opportunity for natural run-off retention is lost and the process, for practical purposes, is irreversible. As these smaller areas are developed and graded, increased run-off will occur, overstressing streams and major wetlands.

Fortunately, most communities still have enough open space to make the course of future development a matter of choice, however, before development pressures become irresistably strong, municipal authorities and private citizens should take advantage of the Commonwealth's aid program for green space preservation. Through their Conservation Commissions, towns may receive up to 75 percent (50 percent Federal, 25 percent State) financial assistance on acquisition projects. Other restrictions short of purchase can also be effective; gifts, conservation easements, and zoning. Whatever the means, delay means the forfeiture of inestimably valuable public benefits.

d. Forms of Acquisition Considered. The natural valley storage areas may be protected by the acquisition in fee, or through easements restricting building and filling of lands which would fulfill the purpose for which the land is to be taken, that is, for preservation in its natural condition. The land acquired in fee, will not include the acquisition of existing improved sites. This will eliminate the need to purchase buildings which are situated on land contiguous to the wetlands. Although the positive method of preserving the wetland is to acquire it in fee, the residents of the Charles have a fondness for "their" river and feel that the land should remain "as is" with no controls placed on the land. However, past trends indicate that the land will not remain the same in 10, 20, or 30 years. To individuals who would not favor outright acquisition, the choice of having an easement placed on their property could be considered. Permanent easements could be obtained that restrict filling and alteration to drainage characteristics with the owner retaining the right to dwell on the land together with its use.

The comments made by property owners at the final public meeting indicated a major concern for retaining ownership of the land. During the advanced engineering and design phase, an analysis will be made to determine which areas would be best acquired and placed in public ownership versus those areas allowed to remain in private ownership with restrictive use.

A sample flowage easement used in the past for reservoir impoundments which has been modified for wetland protection is as follows:

FLOWAGE EASEMENT

The perpetual right, power, privilege, and easement occasionally to overflow, flood, and submerge (the land described in Schedule A) (Tracts _____, _____, and _____) in connection with the operation and maintenance of the _____ project as authorized by the Act of Congress approved _____ together with all right, title, and interest in and to the structures and improvements now situate on the land, except fencing [and also excepting _____ (here identify those structures not designed for human habitation which the Division Engineer determines may remain on the land)]; provided that no structures for human habitation shall be constructed or maintained on the land, that no other structures shall be constructed or maintained on the land except as may be approved in writing by the representative of the United States in charge of the project, and that no excavation shall be conducted and no landfill placed on the land without such approval as to the location and method of excavation and/or placement of landfill and that the existing streamflow shall not be diverted or drainage characteristics altered without such approval; the above estate is taken subject to existing easements for public roads and highways, public utilities, railroads, and pipelines; reserving, however, to the landowners, their heirs and assigns, all such rights and privileges as may be used and enjoyed without interfering with the use of the project for the purposes authorized by Congress or abridging the rights and easement hereby acquired; provided further, that any use of the land shall be subject to Federal and State laws with respect to pollution.

13. REAL ESTATE COST ESTIMATE

a. Scope of Investigation. During the course of this real estate study, an appraiser reviewed public records and contacted and interviewed many knowledgeable persons including private individuals, town officials and personnel from the State Department of Natural Resources. The investigation included a physical inspection of each of the sites to determine the

types of properties involved, their present uses, highest and best uses, and their physical characteristics. Where available, assessors' property maps, delineating the wetland areas, were developed from reduced copies of these maps (1" = 600') to assist in estimating the number of owners affected by the proposed acquisition program, the types of ownerships involved, the values of the properties involved, and the severance damages which might result from the proposed takings. There are presently no assessors' property maps for the town of Bellingham and, consequently, no property maps were developed for Areas R and S. Assessors' maps are currently being prepared under contract.

In addition to specific property and site data, general data was gathered relative to the subject region, towns, neighborhoods, and sites. Zoning information was assembled for each of the sites.

A preliminary market investigation was conducted within the general area of the sites which included personal contact with real estate brokers, appraisers, local assessors, several town engineers and building inspectors, members of community conservation commissions, and other local and State officials and private individuals involved in the purchase and sale of property, or with a general knowledge of real estate values in the subject areas. As a result of this market study, many sales of properties, considered comparable to those affected by the proposed acquisition program, were noted and recorded and much information was gathered relative to the values of the subject sites.

Finally, all of this information was classified and analyzed to form the basis for the real estate values and acquisition costs presented in subsequent sections of this report.

b. Basis for Real Estate Acquisition Costs. Acquisition plans for this project are based on the premise that no existing buildings or other improvements, presently situated within the respective sites, will need to be acquired, nor will access be restricted to these improvements. In those instances where public utilities or municipal or State facilities, such as pipelines, electric or telephone lines, municipal water and sewer facilities, roadways, rail road lines, and other such improvements, are located within a site, it is assumed that a permit or easement will be granted to allow these facilities to remain in place. Where substantial amounts of high land are encompassed by a site, access will be granted over the wetland areas to prevent these higher areas from becoming landlocked or otherwise inaccessible. Generally, the land considered is that land which has been inundated in the recent floods of 1955 and 1968. This estimate is predicated upon the assumption that there is no construction

planned for these sites which will cause unnatural flood conditions, and consequently, there will be no flood damages to existing improvements resulting from other than natural conditions. Consideration was given to all items which would have a bearing on the final real estate costs. These costs were compiled individually for each site and include the following:

(1) Land Values. The values of lands within the proposed taking areas have been estimated individually for each site by use of the market data or comparable sales approach. This approach to value has as its premise a comparison between the property being appraised and recent transactions of similar lands in the vicinity of the property being appraised. Land values presented in this report represent average unit values estimated through a gross appraisal.

(2) Severance Damages. It is anticipated that a majority of the takings required for this project will consist of partial takings which in many cases will cause severance damages to the remaining properties in addition to the value of the lands actually taken. For purposes of clarification, severance damage is the damage to the part not taken which arises by reason of the taking. Elements which contribute to damages of this type include losses in value due to such items as a reduction in the highest and best use of the remainder, the resulting insufficiency of the remainder to support the normal operation, distortion of plottage or shape which handicaps normal use, a more limited or difficult access or the loss of access, and the requirement to relocate or install appurtenant facilities such as fencing, walks, drives, utilities, etc.

(3) Administrative Costs for Acquisition. Experiences of this office in acquiring similar properties in other civil works projects, and experiences of the Corps of Engineers nationally, indicate that administrative costs for acquiring lands within the proposed taking areas will average approximately \$1,200 per tract. These costs include real estate mapping, surveying, legal descriptions, appraising, title evidence, negotiating, closing, and administrative costs for possible condemnations.

(4) Reservation Boundary Surveys and Marking. Current regulations require the marking of all government reservation boundary lines. Based on the most recent contracts issued by this office for this type of work, survey costs for marking the boundary lines of the subject areas are estimated at \$2,000 per mile.

(5) Contingency Allowance. A reasonable contingency allowance is normally applied to all acquisition projects of this type: - to provide for possible adjustments or refinements of the taking lines or unknown ownerships which may develop; for possible increases which may be experienced between the gross appraisal estimates contained in this type of report and the values which will be established by detailed tract appraisals; for adverse condemnation awards; and to allow for actual, practical, and realistic negotiations pursuant to existing regulations.

In recent years, these contingency allowances have normally varied between 15 and 20 percent, depending upon the amount of data available on all aspects of the acquisition, the size of the project and the type, number, and value of the properties to be acquired.

In this instance, however, consideration must be given to the recently passed Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970. Among other requirements applicable to improved properties, this new legislation now makes it mandatory for the government to reimburse owners for certain expenses incidental to the transfer of title to the United States which were formerly noncompensable. These reimbursable expenses include:

(a) recording fees, transfer taxes, and similar expenses incidental to conveying such real property to the United States;

(b) penalty costs for prepayment of any pre-existing recorded mortgages entered into in good faith encumbering such real property; and

(c) the prorata portion of real property taxes paid which are allocable to the United States.

Accordingly, this new legislation is expected to increase real estate costs for new projects and, therefore, considering this legislation, the higher contingency allowance of 20 percent is applied.

c. Real Estate Cost Estimates. Where applicable, the following real estate cost estimates have been prepared using two alternate acquisition plans.

Acquisition Plan No. 1 is based on the premise that all low lands, situated within the areas designated as natural valley storage areas would be acquired. In the case of improved lots or potentially developable lots it is proposed to acquire only restrictive easements over the very low portions of the lots (rear or side yards) thereby allowing for the continued future use or development of the higher front portions of the lots.

Acquisition Plan No. 2 is based on the premise that, although the major portions of the wetland areas would be acquired, no rights would be acquired over any portion of the developed lots or potentially developable lots. This plan, of course, would greatly reduce the acquisition costs and the number of ownerships affected by the proposed acquisition program.

In instances where there are little or no benefits to be derived from alternate plans, only one plan has been proposed. (See Table No. 4.) For detailed estimate of real estate cost for each natural storage area, see Attachment HA.

The \$2 million difference between Plans 1 and 2 reflects a change in the limit of the taking line. Plan No. 1 takes to a given elevation without regard to property lines. Plan No. 2 on the other hand, skirts 177 property owners. By omitting marginal rear lot areas, total land area is reduced by only 313 acres but the cost difference is an impressive \$2 million. Thus, if the taking line is not modified, the project will cost 25 percent more for less than 4 percent additional land. Since these areas abut the more frequently wetted land, and since they are individual lots, it is felt that they are not threatened by further development. Therefore, the recommended plan for acquisition is Plan No. 2: 8,422 acres at an estimated cost of \$7,000,000 which does not include acquiring the lands held in perpetuity by the Trustees of Reservations and the Massachusetts Audubon Society. Although many owners will prefer easements, the real estate estimate is based on current real estate policy directed by Public Law 91-646, 91st Congress, Session 1 wherein full fair market value of property is allowed, therefore the higher cost is used in the cost justification.

d. Management of Natural Valley Storage Areas. The flood water storage capability of the natural valley storage areas will be managed by the United States under the supervision of the Division Engineer, Corps of Engineers, Waltham, Massachusetts. The acquired areas acting as a flood control reservoir will be maintained for the reduction of flood flows throughout the entire watershed and for downstream potential high damage communities.

Periodic inspection of the natural valley storage areas will be made by Division personnel to insure that the areas remain in their natural state.

Although the primary purpose of preserving the wetland areas will be for flood management, much of the wetlands will be managed as a wildlife refuge with limited public access. Table No. 5, which lists the categories of ownership of the 17 natural valley storage areas, indicates that 6,184 acres are now in private ownership. This land will

be considered as a potential wildlife refuge (see attachment II-19, 15 February 1972 letter, U. S. Bureau of Sport Fisheries and Wildlife , Department of the Interior).

The Bureau plans to manage the natural valley storage areas as part of the National Wildlife Refuge Program. Management would be in accordance with the procedures which govern units of the National Wildlife System. It is expected the annual cost of operating and managing will be \$50,000 based on similar units of the National Wildlife Refuge System.

The 429 acres maintained in perpetuity by the Trustees of Reservations and the Massachusetts Audubon Society will continue essentially in its present use. The 589 acres, presently in municipal ownership, will be considered as to its present use, as well as to its adaptability for a refuge.

The 1,220 acres of State land is currently divided as follows:

(1) Corrections Department	77 acres
(2) Mental Health Department	390 acres
(3) Department of Natural Resources	105 acres
(4) Metropolitan District Commission	648 acres

With the exception of category (4), State property will probably continue in its present use, subject only to the right of flowage during flood periods. The 648 acres of wetlands presently owned by the Metropolitan District Commission is being considered by that agency for low intensity recreational use. On this acreage, a flowage easement is sufficient for flood control purposes. However, if it is the wish of the State, the Federal government is willing to acquire the land and make it available under long-term lease arrangements assuming, in addition, one-half of the separable first cost of recreation facilities, in accordance with PL 89-72. During the advanced engineering and design stage of the study, an investigation will be made to determine if there are suitable opportunities for recreational development. The Commonwealth of Massachusetts has indicated their support for Federal assistance should recreation opportunities materialize.

It is a safe assumption that a large number of landowners will prefer easements to sale of their property; the actual amount of land to be acquired in fee will not be known until acquisition procedures begin. A factor to be considered in deciding the form of acquisition, i. e. fee or easement, will be the efficiency of project administration and maintenance. Once that determination has been made for each parcel, detailed procedures for management can be drawn up and a cooperative agreement written with the responsible agency. Also, consideration will be given to coordinating the protection and management elements of the plan at a single level of government.

TABLE NO. 4
CHARLES RIVER STUDY

NATURAL VALLEY STORAGE AREAS

PRELIMINARY ESTIMATE OF REAL ESTATE COSTS

SUMMARY OF FINDINGS

PLAN NO. 1						PLAN NO. 2		
	Area (Acres)	No. of Owners	Land Value	Total R/E Costs	Area (Acres)	No. of Owners	Land Value	Total R/E Costs
AREA A	To be Reconsidered							
"	1,050	75	\$1,212,000	\$1,780,000	1,029	42	\$1,029,000	\$1,500,000
"	285	68	355,000	600,000	250	33	205,000	380,000
"	310	54	340,000	560,000	284	22	203,000	350,000
"	250	14	219,000	360,000	234	8	189,000	320,000
"	135	24	140,000	250,000	118	10	95,000	170,000
"	2,400	250	807,000	1,500,000	2,340	210	603,000	1,200,000
"	960	74	454,000	780,000	907	70	304,000	590,000
"	315	27	340,000	530,000	280	17	226,000	380,000
"	130	12	51,000	100,000	130	12	51,000	100,000
"	400	3	152,000	240,000	395	2	136,000	220,000
"	360	16	125,000	230,000	360	16	125,000	230,000
"	400	55	266,000	480,000	395	20	196,000	350,000
"	150	14	80,000	160,000	150	14	80,000	160,000
"	275	26	120,000	240,000	266	26	90,000	200,000
"	735	135	431,000	850,000	704	68	259,000	550,000
"	---	---	---	---	---	---	---	---
"	180	13	117,000	220,000	180	13	117,000	220,000
"	400	20	196,000	350,000	400	20	196,000	350,000
TOTALS	8,735	880	\$5,405,000	\$9,230,000	8,422	603	\$4,104,000	\$7,270,000

* Single Acquisition Plan
** Eliminated From Consideration

TABLE 5

NATURAL VALLEY STORAGE AREAS
Ownership (Acres)

Area	State	Municipal	Private Conservation Soc.	Private	Total
B	648	39	-	342	1,029
C	-	22	-	228	250
D	-	43	-	241	284
E	-	-	200	34	234
F	-	6	-	112	118
G	77	358	229	1,676	2,340
H	-	16	-	891	907
I	-	-	-	280	280
J	-	3	-	127	130
K	390	-	-	5	395
L	-	-	-	360	360
M	-	2	-	393	395
N	-	5	-	145	150
O	105	-	-	161	266
P	-	80	-	624	704
R	-	15	-	165	180
S	-	-	-	400	400
Totals	1,220	589	429	6,184	8,422

FIRST COST AND ANNUAL CHARGES

14. FIRST COST

The estimated total first cost of the project is \$7.34 million of which \$7 million is the real estate cost. The balance of \$340,000 is designated for engineering and design. To more accurately fix the high water line within selected natural valley storage areas, there is a need for photogrammetric surveys and detailed hydraulic analysis. Also included is the cost for preparing a master plan for each area and preparing special studies (mechanism necessary between communities, State and Federal agencies in operation and maintenance of the project, equitable tax adjustments, regional guidance resource objectives, etc.).

15. ANNUAL CHARGES

An annual operation and maintenance estimate of \$80,000 is based on the record of expenditures made at the adjacent Great Meadows Refuge in Concord, together with the costs of inspection and surveillance by New England Division personnel. Because the productivity of the land ascends monotonically, no estimates for replacement items appear. The total annual charges amount to \$447,000 which include interest on the total investment and its amortization over a 100-year life. A summary of First Cost and Annual Charges for the proposed undertaking is given in Table 6.

BENEFITS

16. TANGIBLE BENEFITS

The recommended acquisition of 8,422 acres of wetlands will minimize increases in annual flood damage due to the loss of valley storage. Benefits are reckoned as the difference between annual losses under present land use conditions and those associated with the projected 1990 loss of 30 percent of valley storage. Annual benefits so derived amount to \$647,000 on an average annual equivalent basis.

Beyond flood control benefits, the wetlands acquired have an average annual conservation benefit of \$184,800 which is based on the preservation of the wetlands noted on the following page.

BENEFITS

<u>Description</u>	<u>Gain in Benefits with Project</u>
Trout Stream Fisheries	\$ 4,200
Warm Water Fisheries	7,500
Wildlife Habitat-Wetlands	38,800
Wildlife Habitat-Water Fowl Hunting	45,700
Nature Study	<u>28,600</u>
TOTAL	\$124,800

These benefits do not include benefits which could be accrued if the areas are developed and managed under the wildlife refuge system.

17. INTANGIBLE BENEFITS

The preservation of wetlands in the face of expanding human populations is one of the most challenging resource management problems. Another vexing problem is how such wetlands can be best enjoyed by the general public. The National Wildlife Refuge System is based on the precept that wildlife on refuges is for the enjoyment of the American public. The Charles River natural valley storage areas may be included in the National Wildlife Refuge System for this purpose. This will bring the marshes under the experienced management of the Bureau of Sport Fisheries and Wildlife in order to achieve the maximum possible human use consistent with wildlife management.

One prime benefit of a National Wildlife Refuge here will be the frequent exposure of urban citizens to the natural environment. Located at the fringe of the Boston Metropolitan area, surrounded by cities and towns, a National Wildlife Refuge will maintain public appreciation of wildlife among urban populations where contact with nature is limited. It is expected that emphasis will be placed on education of youth. The area will be available to many schools for natural history classes. Future generations will visit the area from city homes to observe wildlife in natural surroundings and to appreciate the open space and the natural vistas.

Waterfowl habitat development will be the keystone of the program. By this means, waterfowl production in the Charles River marshes will increase waterfowl numbers in the Atlantic Flyway where they will be enjoyed by Americans along the entire eastern seaboard. The refuge also will provide a stopping place where migratory flights can rest and feed. All wetland-associated wildlife species from songbirds to turtles

TABLE 6

SUMMARY OF FIRST COSTS AND ANNUAL CHARGES
(1971 Price Level)

ENVIRONMENTAL PROTECTION ACTION PLAN
CHARLES RIVER, MASSACHUSETTS

Plan First Cost

Land value (1)	\$3,834,000
Severance damages	952,000
Administrative costs	723,600
Boundary marking	287,200
	<u>\$5,796,800</u>
Contingencies	<u>1,203,200</u>
 Total real estate cost	 \$7,000,000
 Engineering and Design	 <u>340,000</u>
 Total Plan First Cost	 \$7,340,000

Annual Charges (100 year life)

Interest (5-3/8%) (0.053750)	395,000
Amortization (0.00028)	<u>2,000</u>
	397,000
Operation and Maintenance	<u>80,000</u>
 Annual Charges	 \$ 477,000

- (1) Includes State owned land but not land owned in perpetuity by the Massachusetts Audubon Society and the Trustees of Reservations

will be nurtured for public enjoyment. In coordinating with the towns and the Commonwealth, the refuge will become a core unit for management and use of the natural resources of the Charles River watershed and complement other refuges in the system.

Less amenable to quantification are certain other benefits attributable to the project.

a. By protecting marsh areas inundated each spring, their continuing spring recharge to groundwater aquifers is assured. The productivity of existing well fields is thereby protected.

b. Natural flow augmentation of the main stem during periods of reduced precipitation will not be disrupted.

18. ECONOMIC JUSTIFICATION

A comparison of average annual benefits and average annual charges is as follows:

ANNUAL BENEFITS AND COST

Average Annual Benefits

Flood Control	\$647,000
Recreation and fish and wildlife benefits provided by preservation of wetlands	<u>\$124,800</u>
	\$771,800
<u>Average Annual Charges</u>	\$447,000
Benefit/Cost Ratio	1.6 to 1.0

Benefits attributed to recreation and fish and wildlife because of wetlands preservation are minimal and do not include those which might be obtained should the wetlands be enhanced as part of a national wildlife refuge system. Because of the incidental nature of these benefits, it is assumed that all costs of the project will be met with funds of the United States. Local interests are, however, required to submit plans for any proposed constructions which could affect the existing drainage characteristics in the natural valley storage areas. Non-Federal interests are requested to strictly enforce legislation affecting riverbank filling, maintain existing dams, retain public lands and extend legislation to provide relief to communities for potential loss of tax dollars.

DISCUSSION

19. GENERAL

The study determined that there is a need for additional flood management in the Charles River watershed. The needs of the lower watershed were discussed in the Interim Report and will be met by the recommended Warren Avenue Dam and pumping station. The needs of the middle and upper watershed are equally important, although the present potential flood damages are not nearly as severe. The timing of the problem and its solution are extremely critical; and, it is important that positive measures be taken at this time, while the opportunity still exists, to provide a flood management solution which can enhance rather than adversely affect the watershed environment.

The three basic flood management needs of the middle and upper watershed are: (1) to prevent development in flood-prone areas; (2) to assist those who are already located in flood-prone areas; and (3) to minimize future increases in the extent of flood-prone areas.

Measures which can be used to resolve the first two flood management needs are described in detail in several parts of the Main Report and Appendix C. Briefly, they consist of delineation of the flood plain through available flood plain information programs; application of existing regulation legislation (zoning, building codes, etc.); implementation of existing State conservation laws (Hatch Act, Inland Wetlands Act, etc.); provision of technical assistance, for example, relating to flood proofing; and provision of flood insurance. Structural solutions to protect existing development in the flood plain did not prove to be economically feasible.

Positive measures are necessary to assure that future flood loss potential is kept to a minimum. Of the methods discussed in earlier sections of this report, Federal acquisition of regionally significant natural valley storage areas appears to be the most logical approach. It provides key control of regional flood management, and yet is compatible and complementary with local and State flood management actions. Finally, acquisition of the 17 natural storage areas provides the opportunity for multiple use of the natural resources of the watershed.

All communities containing natural valley storage areas will benefit from their preservation to some extent. The aggregate of the areas will produce major benefits in the downstream areas described above but the areas immediately downstream of each individual area, or in some instances, within a portion of a given area, will have more direct benefits.

Located above the Route 109 bridge on the Millis-Medfield town line are 4,000 acres of natural valley storage. If 10 percent, 20 percent, 30 percent, or 40 percent of the storage were to be lost, flood stages would be 1.0 feet, 2.2 feet, 3.6 feet, and 5.0 feet higher than the 1955 or 1968 high water mark at the Route 109 bridge. Flood waters which in the past have generally stayed a foot or so below critical heights of many homes and industries would cause serious damages to areas not previously affected. A hydraulic analysis has determined the effect of valley storage loss on discharges at key points along the river. The attached table (Table No. 7) shows the percent loss in upstream storage with the estimated increase in discharges and corresponding elevations at eight locations in the Charles River watershed. The zero percent loss column was based on the floods of August 1955 and March 1968. An upper limit of 40 percent loss in valley storage was selected representing a discharge of 6,000 cfs at Charles River Village. However, it has been estimated that storage losses of 60, 80, and 90 percent would result in discharges of about 8,000, 12,000, and 15,000 cfs, respectively and cause correspondingly greater heights in flood waters.

The land acquired could be operated and maintained as a wildlife refuge with provision for limited public access. It is anticipated minimum work will be needed in the areas, such as making pot holes or dikes to enhance the wildlife habitat and also providing access points for fishermen, canoeists, and hunters.

Since the initiation of the Charles River Study, many persons and local agencies in the watershed have expressed great interest and enthusiasm in the canoeing opportunities of the Charles. As a basic part of the study, members of the New England Division of the Corps of Engineers floated the Charles by canoe in May 1967, a time when high water conditions prevailed. The canoe team had the opportunity to locate favorable sites for launching or landing canoes and to collect other information of value to people who enjoy this kind of river recreation. The sites are listed in Table HB-1 and are shown on Plate No. 1 and in the Main Report. It is hoped that this information will be useful to people who enjoy canoeing and will become the basis for more use of this beautiful river by canoe.

During the advanced engineering and design stage of the study, Master plans for each area will be developed and an investigation will be made to determine recreational canoe launching facilities at sites contiguous to the natural valley storage areas. Non-Federal entities may assume responsibility for developing and Federal participation could be available under P. L. 89-72

A key problem is that of tax losses to communities wherein Federal owned lands occur. Currently there is State legislation which provides that certain communities may be reimbursed for taxes lost by reason of property taken for flood control reservoirs either by the State or Federal agencies. All that is required is that a local representative submit a resolution.

CONCLUSIONS

20. GENERAL

Flooding in the middle and upper Charles is not now a serious problem, but with continued encroachment into the flood plains and loss of the wetlands due to urban expansion, heavy damages will occur in future floods. In the event of a recurrence of the past major floods, losses amounting to over \$12 million would be experienced. It is concluded that the magnitude of the potential flood losses are sufficient to warrant the Federal acquisition of the natural valley storage areas as described in this report. The proposed flood management project, with an estimated first cost of \$7.34 million, has a benefit-to-cost ratio of 1.6 to 1.0

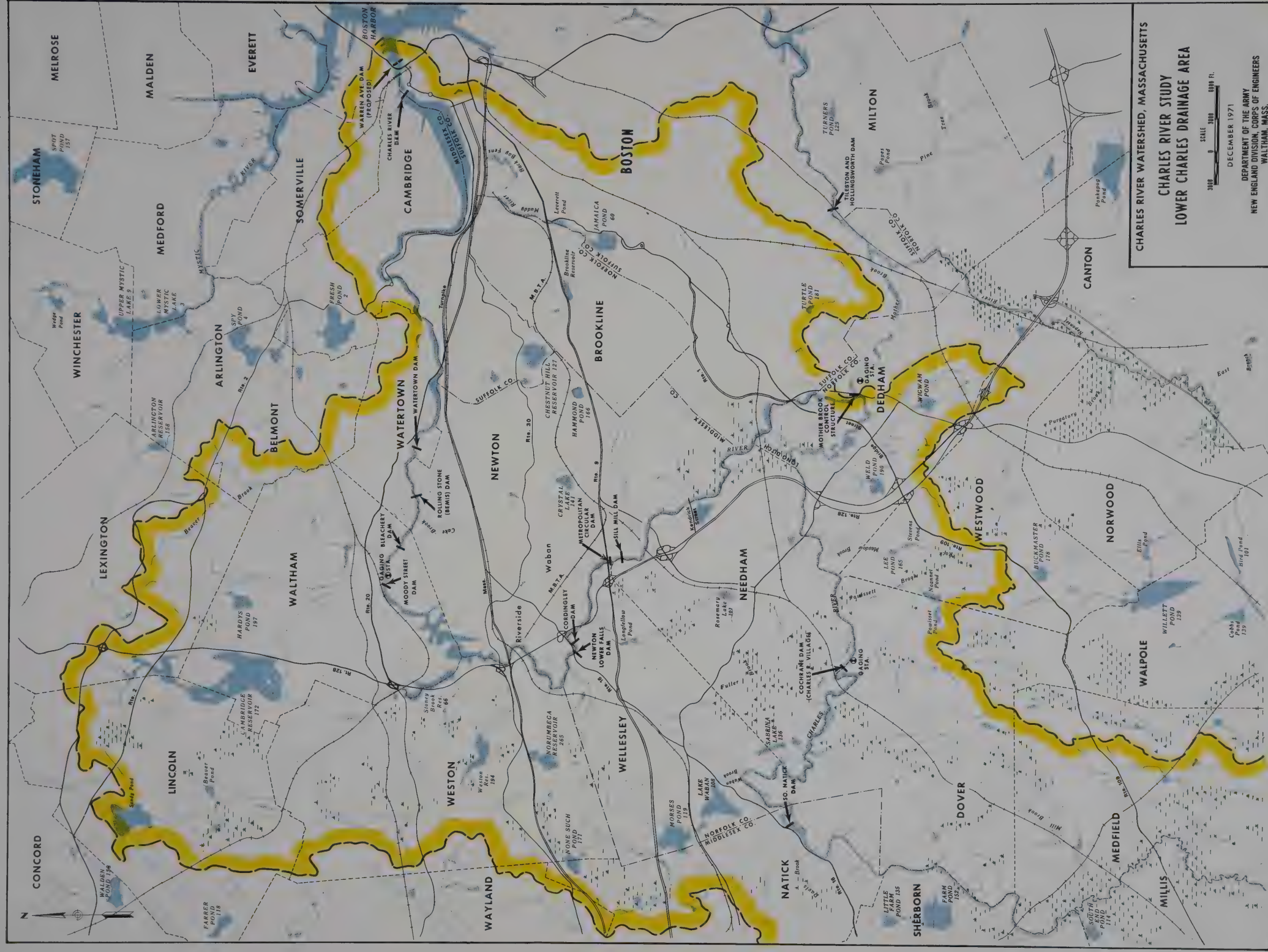
TABLE NO. 7

PERCENT LOSS IN UPSTREAM STORAGEIncrease in Elevation-Discharge

Location	CFS*	Elev.*	Increase in Elevation-Discharge						Elev.	CFS	Elev.
			0	10	20	30	40				
Rte 109 Bridge Medfield	2,800	121.7	3,300	122.7	3,830	123.9	4,520	125.3	5,200	126.7	
Charles River Village - USGS	3,220	98.5	3,800	99.4	4,400	100.3	5,200	101.3	6,000	102.3	
Charles River at Mother Brook	2,200	89.7	2,800**	90.5	3,400	91.3	4,200	92.4	5,000	93.3	
Mother Brook Dedham - USGS	1,040	87.2	1,230	88.0	1,420	88.9	1,680	90.2	1,940	91.3	
Kendrick Street Bridge	2,200	89.7	2,600	90.6	3,000	91.4	3,550	92.5	4,100	93.6	
Wellesley Office Park	2,390	65.3	2,820	65.9	3,260	66.4	3,860	67.0	4,450	67.7	
Newton Lower Falls (NYC RR bridge)	2,400	42.2	2,830	42.9	3,280	43.5	3,880	44.3	4,470	45.0	
Waltham - USGS	2,670	25.2	3,150	25.6	3,650	26.0	4,300	26.6	4,980	27.0	

*Based on experienced floods of 1955 and 1968

**Based on maximum discharge of 1,000 cfs on Mother Brook



CHARLES RIVER WATERSHED, MASSACHUSETTS
CHARLES RIVER STUDY
LOWER CHARLES DRAINAGE AREA

3000 0 SCALE 1000 500 FT.

DECEMBER 1971
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.

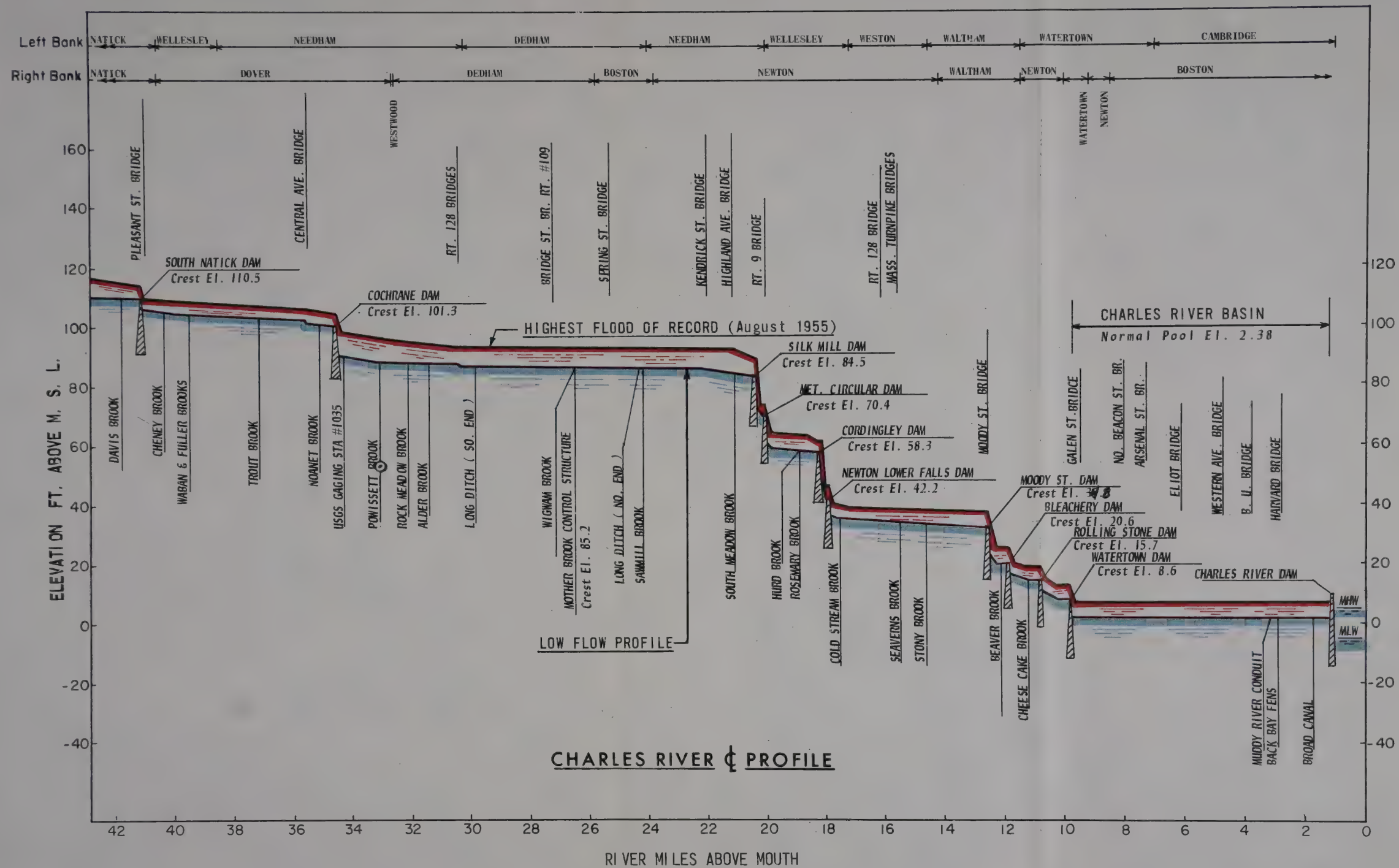


CHARLES RIVER WATERSHED, MASSACHUSETTS

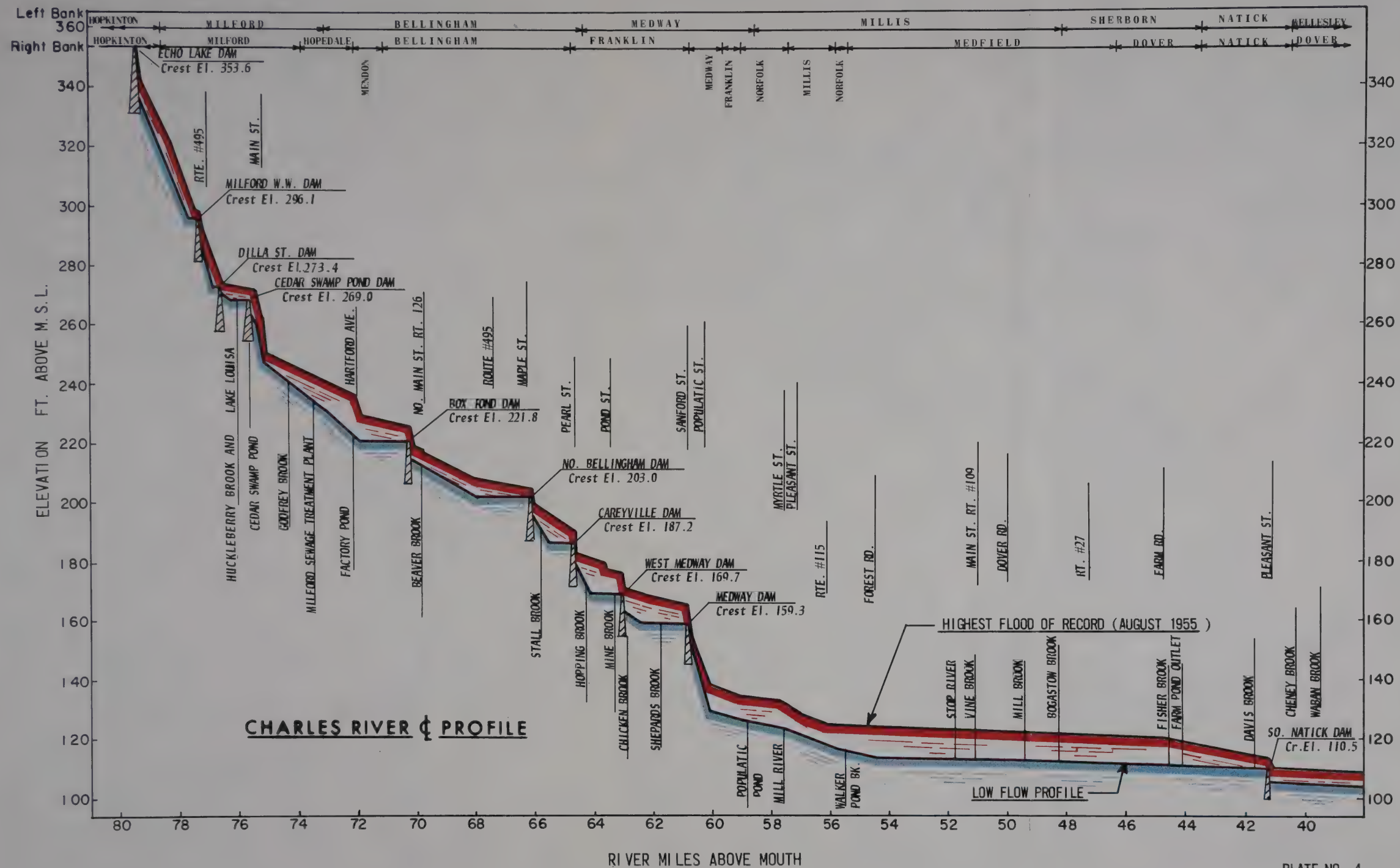
CHARLES RIVER STUDY UPPER CHARLES DRAINAGE AREA

SCALE 0 3000 6000 FT.

DECEMBER 1971
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.



CHARLES RIVER & PROFILE



ATTACHMENT HA
REAL ESTATE
COST ESTIMATE

AREA B - NEEDHAM, NEWTON, BOSTON, DEDHAM, MASS.

ACQUISITION PLAN NO. 1 (Acquiring Entire Site - Excluding Existing Improvements)

<u>Type of Ownerships</u>	<u>a. LAND OWNERSHIP 1/</u>		<u>Total Acres</u>	<u>No. of Owners</u>
	<u>Fee Acres</u>	<u>Easement Acres</u>		
Federal	--	--	--	--
State	648	--	648	1 2/
Municipal	39	--	39	2 3/
Private Conservation Soc.	--	--	--	--
Private	342	21	363	72
Totals	1,029	21	1,050 4/	75

<u>b. ESTIMATED LAND VALUES</u>			
<u>Recommended Fee Estates</u>	<u>Average P/A Unit Value</u>	<u>Acres</u>	<u>Estimated Fair Market Value</u>
	<u>\$1,000</u>	<u>1,029</u>	<u>\$1,029,000 5/ 6/</u>
Unimproved Land			
<u>Recommended Easement Estates</u>	<u>Lots Subject To Easements 7/</u>	<u>Acres</u>	<u>Estimated Fair Market Value 8/</u>
Developed Residential Lots	35	13	\$ 105,000
Potential Residential Lots	26	8	78,000
Total	61	21	\$ 183,000
Total Lands		1,050	\$1,212,000 9/

TOTAL VALUE OF FEE & EASEMENT AREAS (ROUNDED) \$1,212,000

<u>c. SUMMARY OF REAL ESTATE ACQUISITION COSTS</u>	
Total Land Values	\$1,212,000
Severance Damages (Fee Estates)	150,000
Administrative Costs (75 Ownerships at \$1,200 Each)	90,000
Reservation Boundary Marking (14.7 Miles at \$2,000 Per Mile)	29,400
Contingencies (20% of Above)	296,280
Total Real Estate Costs	\$1,777,680
TOTAL REAL ESTATE COSTS (ROUNDED)	<u>\$1,780,000</u>

- 1/ Land ownership data based on a study of Assessor's records and property maps.
- 2/ Metropolitan District Commission.
- 3/ Includes 22 acres owned by the City of Newton and 17 acres owned by the City of Boston.
- 4/ All land in Needham and Dedham is flood plain zoned.
- 5/ Includes the 648 acres of State-owned land and 39 acres of Municipally-owned land.
- 6/ Land value estimate does not include purchase of State or Municipal water and sewage facilities.
- 7/ Easements recommended over low portions of lots (rear or side yards).
- 8/ Represents value of easements and damages resulting from imposition of easements.
- 9/ The majority of the wetland area in the City of Boston was eliminated from this site due to the fact that it is cemetery land or land owned by the City of Boston and used for dump purposes. The prohibitive costs of acquiring this land and the anticipated problems usually experienced in this type of acquisition make this proposed taking most unrealistic.

AREA B - NEEDHAM, NEWTON, BOSTON, DEDHAM, MASS.

ACQUISITION PLAN NO. 2 (Excluding All Developed Lots and Potential Lots)

Type of Ownerships	a. LAND OWNERSHIP 1/		Total Acres	No. of Owners
	Fee Acres	Easement Acres		
Federal	--	--	--	--
State	648	--	648	1 2/
Municipal	39	--	39	2 3/
Private Conservation Soc	--	--	--	--
Private	342	--	342	39
Totals	1,029	--	1,029 4/	42

Recommended Fee Estates	b. ESTIMATED LAND VALUES		Estimated Fair Market Value
	Average P/A Unit Value	Acres	
Unimproved Land	\$1,000	1,029	\$1,029,000 5/ 6/ 7/

Recommended Easement Estates
None

TOTAL VALUE OF FEE AREA (ROUNDED) \$1,029,000

c. SUMMARY OF REAL ESTATE ACQUISITION COSTS	
Total Land Values	\$1,029,000
Severance Damages	150,000
Administrative Costs (42 Ownerships at \$1,200 Each)	50,400
Reservation Boundary Marking (14.7 Miles at \$2,000 Per Mile)	29,400
Contingencies (20% of Above)	251,760
Total Real Estate Costs	<u>\$1,510,560</u>

TOTAL REAL ESTATE COSTS (ROUNDED) \$1,500,000

- 1/ Land ownership data based on a study of Assessor's records and property maps.
- 2/ Metropolitan District Commission
- 3/ Includes 22 acres owned by the City of Newton and 17 acres owned by the City of Boston.
- 4/ All land in Needham and Dedham is flood plain zoned.
- 5/ Includes 648 acres of State-owned land and 39 acres of Municipally-owned land.
- 6/ Land value estimate does not include purchase of State or Municipal water and Sewage facilities.
- 7/ The majority of the wetland area in the City of Boston was eliminated from this site due to the fact that it is cemetery land or land owned by the City of Boston and used for dump purposes. The prohibitive costs of acquiring this land and the anticipated problems usually experienced in this type of acquisition make this proposed taking most unrealistic.

AREA C - DOVER, MASS.

ACQUISITION PLAN NO. 1 (Acquiring Entire Site - Excluding Existing Improvements)

Type of Ownerships	a. LAND OWNERSHIP 1/		Total Acres	No. of Owners
	Fee Acres	Easement Acres		
Federal	--	--	--	--
State	--	--	--	--
Municipal	22	--	22	1
Private Conservation Soc.	--	--	--	--
Private	228	35	263	67
Totals	250	35	285 2/	68

Recommended Fee Estates	b. ESTIMATED LAND VALUES		Estimated Fair Market Value
	Average P/A Unit Value	Acres	
Unimproved Land (Very Low & Wet)	\$ 700	190	\$133,000
Unimproved Land (Low)	1,200	60	72,000
		250	205,000 3/

Recommended Easement Estates	Lots Subject To Easements 4/		Acres	Estimated Fair Market Value	5/
Developed Residential Lots	35		24	\$105,000	
Potential Residential Lots	15		11	45,000	
Total	40		35	\$150,000	

Total Lands 285 \$355,000

TOTAL VALUE OF FEE & EASEMENT AREAS (ROUNDED) \$355,000

c. SUMMARY OF REAL ESTATE ACQUISITION COSTS	
Total Land Values	\$355,000
Severance Damages (Fee Estates)	55,000
Administrative Costs (68 Ownerships at \$1,200 Each)	81,600
Reservation Boundary Marking (7.2 Miles at \$2,000 Per Mile)	14,400
Contingencies (20% of Above)	101,200
Total Real Estate Costs	\$607,200

TOTAL REAL ESTATE COSTS (ROUNDED) \$600,000

- 1/ Land ownership data based on a study of Assessor's records and property maps.
- 2/ Majority of site is zoned as a conservancy district (flood plain).
- 3/ Includes the 22 acres of Municipally-owned land.
- 4/ Easements recommended over low portions of lots (rear or side yards).
- 5/ Represents value of easements and damages resulting from imposition of easements.

AREA C - DOVER, MASS.

ACQUISITION PLAN NO. 2 (Excluding All Developed Lots and Potential Lots)

<u>Type of Ownerships</u>	<u>a. LAND OWNERSHIP 1/</u>		<u>Total Acres</u>	<u>No. of Owners</u>
	<u>Fee Acres</u>	<u>Easement Acres</u>		
Federal	--	--	--	--
State	--	--	--	--
Municipal	22	--	22	1
Private Conservation Soc	--	--	--	--
Private	228	--	228	32
Totals	250	--	250	33

<u>Recommended Fee Estates</u>	<u>b. ESTIMATED LAND VALUES</u>		<u>Estimated Fair Market Value</u>
	<u>Average P/A Unit Value</u>	<u>Acres</u>	
Unimproved Land (Very Low & Wet)	\$ 700	190	\$133,000
Unimproved Land (Low)	1,200	60	72,000
Total		250	\$205,000 3/

Recommended Easement Estates
None

TOTAL VALUE OF FEE AREA (ROUNDED) \$205,000

<u>c. SUMMARY OF REAL ESTATE ACQUISITION COSTS</u>	
Total Land Values	\$205,000
Severance Damages	55,000
Administrative Costs (33 Ownerships at \$1,200 Each)	39,600
Reservation Boundary Marking (7.2 Miles at \$2,000 Per Mile)	14,400
Contingencies (20% of Above)	62,800
Total Real Estate Costs	\$376,800
TOTAL REAL ESTATE COSTS (ROUNDED)	<u>\$380,000</u>

1/ Land ownership data based on a study of Assessor's records and property maps.

2/ Majority of site is zoned as a conservancy district (flood plain).

3/ Includes the 22 acres of Municipally-owned land.

AREA D - NEEDHAM, MASS.

ACQUISITION PLAN NO. 1 (Acquiring Entire Site - Excluding Existing Improvements)

Type of Ownerships	a. LAND OWNERSHIP 1/		Total Acres	No. of Owners
	Fee Acres	Easement Acres		
Federal	--	--	--	--
State	--	--	--	--
Municipal	43	--	43 2/	1
Private Conservation Soc.	--	--	--	--
Private	161	106	267	53
Totals	204	106	310 3/	54

b. ESTIMATED LAND VALUES			
Recommended Fee Estates	Average P/A Unit Value	Acres	Estimated Fair Market Value
Unimproved Land (Very Low & Wet)	\$ 700	16	\$114,800
Unimproved Land (Low)	1,200	1.0	48,000
Totals		20	\$162,800 4/
Recommended Easement Estates	Lots Subject To Easements 5/		Estimated Fair Market Value 6/
		Acres	
Developed Commercial Lot	1	--	\$ 4,000
Developed Residential Lots	34	18	98,000
Potential Residential Lots	15	8	35,000
Radio Antennae Site (WHDH)	--	80	40,000 7/
Totals	50	106	\$177,000
<u>Total Lands</u>		<u>310</u>	<u>\$339,800</u>

TOTAL VALUE OF FEE & EASEMENT AREAS (ROUNDED) \$340,000

c. SUMMARY OF REAL ESTATE ACQUISITION COSTS	
Total Land Values	\$340,000
Severance Damages (Fee Estates)	50,000
Administrative Costs (54 Ownerships at \$1,200 Each)	64,800
Reservation Boundary Marking (5.6 Miles at \$2,000 Per Mile)	11,200
Contingencies (20% of Above)	93,200
Total Real Estate Costs	\$559,200
 TOTAL REAL ESTATE COSTS (ROUNDED)	 <u>\$560,000</u>

- 1/ Land ownership data based on a study of assessor's records and property maps.
- 2/ Excluding Town dump land.
- 3/ Entire site flood plain zoned.
- 4/ Includes the 43 acres of Municipally-owned land. Estimate does not include purchase of the Town dump.
- 5/ Easements recommended over low portions of lots (rear or side yards).
- 6/ Represents value of easements and damages resulting from imposition of easements.
- 7/ Does not include purchase of radio tower or appurtenant facilities.

AREA D - NEEDHAM, MASS.

ACQUISITION PLAN NO. 2 (Excluding All Developed Lots and Potential Lots)

<u>Type of Ownerships</u>	<u>a. LAND OWNERSHIP 1/</u>		<u>Total Acres</u>	<u>No. of Owners</u>
	<u>Fee Acres</u>	<u>Easement Acres</u>		
Federal	--	--	--	--
State	--	--	--	--
Municipal	43	--	43 2/	1
Private Conservation Soc.	--	--	--	--
Private	161	80	241	21
Totals	204	80	284 3/	22

<u>b. ESTIMATED LAND VALUES</u>			
<u>Recommended Fee Estates</u>	<u>Average P/A Unit Value</u>	<u>Acres</u>	<u>Estimated Fair Market Value</u>
Unimproved Land (Very Low & Wet)	\$ 700	164	\$114,800
Unimproved Land (Low)	1,200	40	48,000
Totals		204	\$162,800 4/
<u>Recommended Easement Estates</u>		<u>Acres</u>	<u>Estimated Fair Market Value</u>
Radio Antennae Site (WHDH)		80	\$ 40,000 5/
<u>Total Lands</u>		284	\$202,800

TOTAL VALUE OF FEE & EASEMENT AREAS (ROUNDED) \$203,000

<u>c. SUMMARY OF REAL ESTATE ACQUISITION COSTS</u>	
Total Land Values	\$203,000
Severance Damages (Fee Estates)	50,000
Administrative Costs (22 Ownerships at \$1,200 Each)	26,400
Reservation Boundary Marking (5.6 Miles at \$2,000 Per Mile)	11,200
Contingencies (20% of Above)	58,120
Total Real Estate Costs	\$348,720
TOTAL REAL ESTATE COSTS (ROUNDED)	<u>\$350,000</u>

- 1/ Land ownership data based on a study of Assessor's records and property maps.
 2/ Excluding Town dump land.
 3/ Entire site flood plain zoned.
 4/ Includes the 43 acres of Municipally-owned land. Estimate does not include purchase of the Town dump.
 5/ Does not include purchase of radio tower or appurtenant facilities.

AREA E - SHERBORN and NATICK, MASS.

ACQUISITION PLAN NO. 1 (Acquiring Entire Site - Excluding Existing Improvements)

<u>Type of Ownerships</u>	<u>a. LAND OWNERSHIP 1/</u>		<u>Total Acres</u>	<u>No. of Owners</u>
	<u>Fee Acres</u>	<u>Easement Acres</u>		
Federal	--	--	--	--
State	--	--	--	--
Municipal	--	--	--	--
Private Conservation Soc.	200	--	200	1 2/
Private	34	16	50	13
Totals	234	16	250 3/	14

<u>b. ESTIMATED LAND VALUES</u>			
<u>Recommended Fee Estates</u>	<u>Average P/A</u>		<u>Estimated Fair Market Value</u>
	<u>Unit Value</u>	<u>Acres</u>	
Unimproved Land (Very Low & Wet)	\$ 700	184	\$128,800
Unimproved Land (Low)	1,200	50	60,000
Totals		234	\$188,800 4/
<u>Recommended Easement Estates</u>	<u>Lots Subject To Easements 5/</u>		<u>Estimated Fair Market Value 6/</u>
		<u>Acres</u>	
Developed Residential Lots	5	7	\$ 10,000
Potential Residential Lots	7	9	20,000
Totals	12	16	\$ 30,000
<u>Total Lands</u>		250	\$218,800

TOTAL VALUE OF FEE & EASEMENT AREAS (ROUNDED) \$219,000

<u>c. SUMMARY OF REAL ESTATE ACQUISITION COSTS</u>	
Total Land Values	\$219,000
Severance Damages (Fee Estates)	55,000
Administrative Costs (14 Ownerships at \$1,200 Each)	16,800
Reservation Boundary Marking (5.3 Miles at \$2,000 Per Mile)	10,600
Contingencies (20% of Above)	60,280
Total Real Estate Costs	\$361,680
TOTAL REAL ESTATE COSTS (ROUNDED)	<u>\$360,000</u>

- 1/ Land ownership data based on a study of Assessor's records and property maps.
 2/ Owned by Massachusetts Audubon Society.
 3/ A very small portion of the land in Sherborn is zoned as a flood plain district - 25' horizontal from streams, brooks, and Little Farm Pond.
 4/ Includes the 200 acres of conservation society land.
 5/ Easements recommended over low portions of lots (rear or side yards).
 6/ Represents value of easements and damages resulting from imposition of easements.

AREA E - SHERBORN and NATICK, MASS.

ACQUISITION PLAN NO. 2 (Excluding All Developed Lots and Potential Lots)

<u>Type of Ownerships</u>	<u>a. LAND OWNERSHIP 1/</u>		<u>Total Acres</u>	<u>No. of Owners</u>
	<u>Fee Acres</u>	<u>Easement Acres</u>		
Federal	--	--	--	--
State	--	--	--	--
Municipal	--	--	--	--
Private Conservation Soc.	200	--	200	1 2/
Private	34	--	34	7
Totals	234	--	234 3/	8

<u>Recommended Fee Estates</u>	<u>b. ESTIMATED LAND VALUES</u>		<u>Estimated Fair Market Value</u>
	<u>Average P/A Unit Value</u>	<u>Acres</u>	
Unimproved Land (Very Low & Wet)	\$ 700	184	\$128,800
Unimproved Land (Low)	1,200	50	60,000
Totals		234	\$188,800 4/

Recommended Easement Estates
None

TOTAL VALUE OF FEE AREA (ROUNDED) \$189,000

<u>c. SUMMARY OF REAL ESTATE ACQUISITION COSTS</u>	
Total Land Values	\$189,000
Severance Damages	55,000
Administrative Costs (8 Ownerships at \$1,200 Each)	9,600
Reservation Boundary Marking (5.3 Miles at \$2,000 Per Mile)	10,600
Contingencies (20% of Above)	52,840
Total Real Estate Costs	<u>\$317,040</u>

TOTAL REAL ESTATE COSTS (ROUNDED) \$320,000

- 1/ Land ownership data based on a study of Assessor's records and property maps.
2/ Owned by Massachusetts Audubon Society.
3/ A very small portion of the land in Sherborn is zoned as a flood plain district -
25' horizontal from streams, brooks, and Little Farm Pond.
4/ Includes the 200 acres of conservation society land.

AREA F - SHERBORN, MASS.

ACQUISITION PLAN NO. 1 (Acquiring Entire Site - Excluding Existing Improvements)

Type of Ownerships	a. LAND OWNERSHIP 1/		Total Acres	No. of Owners
	Fee Acres	Easement Acres		
Federal	--	--	--	--
State	--	--	--	--
Municipal	6	--	6	1
Private Conservation Soc:	--	--	--	--
Private	112	17	129	23
Totals	118	17	135	24

b. ESTIMATED LAND VALUES			
Recommended Fee Estates	Average P/A Unit Value	Acres	Estimated Fair Market Value
Unimproved Land (Very Low & Wet)	\$ 700	93	\$65,100
Unimproved Land (Low)	1,200	25	30,000
Totals		118	\$95,100 2/
Recommended Easement Estates	Lots Subject To Easements 3/	Acres	Estimated Fair Market Value 4/
Developed Residential Lots	13	5	\$19,000
Potential Residential Lots	12	12	26,000
Totals	25	17	\$45,000
Total Lands		135	\$140,100

TOTAL VALUE OF FEE & EASEMENT AREAS (ROUNDED) \$140,000

c. SUMMARY OF REAL ESTATE ACQUISITION COSTS	
Total Land Values	\$140,000
Severance Damages (Fee Estates)	30,000
Administrative Costs (24 Ownerships at \$1,200 Each)	28,800
Reservation Boundary Marking (2.9 Miles at \$2,000 Per Mile)	5,800
Contingencies (20% of Above)	40,920
Total Real Estate Costs	\$245,520
TOTAL REAL ESTATE COSTS (ROUNDED)	\$250,000

- 1/ Land ownership data based on a study of Assessor's records and property maps.
 2/ Includes the 6 acres of Municipally-owned land.
 3/ Easements recommended over low portions of lots (rear or side yards).
 4/ Represents value of easements and damages resulting from easements.

AREA F - SHERBORN, MASS.

ACQUISITION PLAN NO. 2 (Excluding All Developed Lots and Potential Lots)

<u>Type of Ownerships</u>	<u>a. LAND OWNERSHIP 1/</u>		<u>Total Acres</u>	<u>No. of Owners</u>
	<u>Fee Acres</u>	<u>Easement Acres</u>		
Federal	--	--	--	--
State	--	--	--	--
Municipal	6	--	6	1
Private Conservation Soc.	--	--	--	--
Private	112	--	112	9
Totals	118	--	118	10

<u>Recommended Fee Estates</u>	<u>b. ESTIMATED LAND VALUES</u>		<u>Estimated Fair Market Value</u>
	<u>Average P/A Unit Value</u>	<u>Acres</u>	
Unimproved Land (Very Low & Wet)	\$ 700	93	\$65,100
Unimproved Land (Low)	1,200	25	30,000
Totals		118	\$95,100 2/

Recommended Easement Estates
None

TOTAL VALUE OF FEE AREA (ROUNDED) \$95,000

<u>c. SUMMARY OF REAL ESTATE ACQUISITION COSTS</u>	
Total Land Values	\$ 95,000
Severance Damages	30,000
Administrative Costs (10 Ownerships at \$1,200 Each)	12,000
Reservation Boundary Marking (2.9 Miles at \$2,000 Per Mile)	5,800
Contingencies (20% of above)	28,560
Total Real Estate Costs	\$171,360
TOTAL REAL ESTATE COSTS (ROUNDED)	<u>\$170,000</u>

1/ Land ownership data based on a study of Assessor's records and property maps.

2/ Includes the 6 acres of Municipally-owned land.

AREA G - MILLIS MEDFIELD, WALPOLE, NORFOLK, MASS.

ACQUISITION PLAN NO. 1 (Acquiring Entire Site - Excluding Existing Improvements)

Type of Ownerships	a. LAND OWNERSHIP 1/		Total Acres	No. of Owners
	Fee Acres	Easement Acres		
Federal	--	--	--	--
State	77	--	77	1
Municipal	358	--	358	4 2/
Private Conservation Soc.	229	--	229	1 3/
Private	1,686	50	1,736	244
Totals	2,350	50	2,400 4/	250

b. ESTIMATED LAND VALUES			
Recommended Fee Estates	Average P/A Unit Value	Acres	Estimated Fair Market Value
Unimproved Commercial & Industrial Land (Low - Front)	\$3,000	10	\$ 30,000
Unimproved Industrial Land (Low)	500	50	25,000
Unimproved Land (Very Low & Wet)	200	1,890	378,000
Unimproved Land (Low)	500	400	200,000
Totals		2,350	\$633,000 5/ 6/

Recommended Easement Estates	Lots Subject To Easements 7/	Acres	Estimated Fair Market Value 8/
Developed Commercial Lots	3	1	\$ 9,000
Developed Residential Lots	60	33	120,000
Potential Residential Lots	30	16	45,000
Totals	93	50	\$174,000

<u>Total Lands</u>	<u>2,400</u>	<u>\$807,000</u>
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TOTAL VALUE OF FEE & EASEMENT AREAS (ROUNDED) \$ 807,000

c. SUMMARY OF REAL ESTATE ACQUISITION COSTS	
Total Land Values	\$ 807,000
Severance Damages (Fee Estates)	100,000
Administrative Costs (250 Ownerships at \$1,200 Each)	300,000
Reservation Boundary Marking (25 Miles at \$2,000 Per Mile)	50,000
Contingencies (20% of Above)	251,400
Total Real Estate Costs	<u>\$1,508,400</u>

TOTAL REAL ESTATE COSTS (ROUNDED) \$1,500,000

- 1/ Land ownership data based on a study of Assessor's records and property maps.
 2/ Includes 90 acres owned by the Town of Millis, 245 acres owned by the Town of Medfield,
 6 acres owned by the Town of Walpole, and 17 acres owned by the Town of Norfolk.
 3/ Owned by Trustees of Reservations.

AREA G - MILLIS, MEDFIELD, WALPOLE, NORFOLK, MASS.

ACQUISITION PLAN NO. 1 (Acquiring Entire Site - Excluding Existing Improvements)

- 4/ Entire site, with the exception of the small area in Walpole, is flood plain zoned.
- 5/ Includes State, Municipal, and Private Conservation Society land.
- 6/ Land value estimate does not include purchase of Municipal and State water and sewerage facilities located within this site nor does it include purchase of the Millis Town dump.
- 7/ Easements recommended over low portions of lots (rear or side yards).
- 8/ Represents value of easements and damages resulting from imposition of easements.

AREA G - MILLIS, MEDFIELD, WALPOLE, NORFOLK, MASS.

ACQUISITION PLAN NO. 2 (Excluding All Developed Lots and Potential Lots)

Type of Ownerships	a. LAND OWNERSHIP 1/		Total Acres	No. of Owners
	Fee Acres	Easement Acres		
Federal	--	--	--	--
State	77	--	77	1
Municipal	358	--	358	4 2/
Private Conservation Soc.	229	--	229	1 3/
Private	1,676	--	1,676	204
Totals	2,340	--	2,340	4/ 210

Recommended Fee Estates	b. ESTIMATED LAND VALUES		Estimated Fair Market Value
	Average P/A Unit Value	Acres	
Unimproved Industrial Land (Low - Rear)	\$500	50	\$ 25,000
Unimproved Land (Very Low & Wet)	200	1,890	378,000
Unimproved Land (Low)	500	400	200,000
Totals		2,340	\$603,000 5/ 6/

Recommended Easement Estates
None

TOTAL VALUE OF FEE AREA (ROUNDED) \$ 603,000

c. SUMMARY OF REAL ESTATE ACQUISITION COSTS

Total Land Values	\$ 603,000
Severance Damages	100,000
Administrative Costs (210 Ownerships at \$1,200 Each)	252,000
Reservation Boundary Marking (25 Miles at \$2,000 Per Mile)	50,000
Contingencies (20% of Above)	201,000
Total Real Estate Costs	\$1,206,000

TOTAL REAL ESTATE COSTS (ROUNDED) \$1,200,000

- 1/ Land ownership data based on a study of Assessor's records and property maps.
- 2/ Includes 90 acres owned by the Town of Millis, 245 acres owned by the Town of Medfield, 6 acres owned by the Town of Walpole, and 17 acres owned by the Town of Norfolk.
- 3/ Owned by Trustees of Reservations.
- 4/ Entire site, with the exception of the small area in Walpole, is flood plain zoned.
- 5/ Includes State, Municipal, and Private Conservation Society land.
- 6/ Land value estimate does not include purchase of Municipal and State water and sewerage facilities located within this site nor does it include purchase of the Millis Town dump.

AREA H - MILLIS and MEDWAY, MASS.

ACQUISITION PLAN NO. 1 (Acquiring Entire Site - Excluding Existing Improvements)

<u>Type of Ownerships</u>	<u>a. LAND OWNERSHIP 1/</u>		<u>Total Acres</u>	<u>No. of Owners</u>
	<u>Fee Acres</u>	<u>Easement Acres</u>		
Federal	--	--	--	--
State	--	--	--	--
Municipal	16	--	16	1
Private Conservation Soc.	--	--	--	--
Private	941	3	944	73
Totals	957	3	960	74

<u>Recommended Fee Estates</u>	<u>b. ESTIMATED LAND VALUES</u>		<u>Estimated Fair Market Value</u>
	<u>Average P/A Unit Value</u>	<u>Acres</u>	
Unimproved Industrial Land (Low - Front)	\$3,000	30	\$ 90,000
Unimproved Industrial Land (Low - Rear)	500	60	30,000
Unimproved Industrial Land (Very Low & Wet)	300	142	42,600
Unimproved Residential Land (Low - Front)	2,000	20	40,000
Unimproved Land (Low)	500	100	50,000
Unimproved Land (Very Low & Wet)	300	605	181,500
Totals		957	\$434,100 2/

<u>Recommended Easement Estates</u>	<u>Lots Subject To Easements 3/</u>		<u>Estimated Fair Market Value 4/</u>
	<u>Acres</u>		
Developed Commercial & Industrial Lots	5	3	\$ 20,000
<u>Total Lands</u>		960	\$454,100

TOTAL VALUE OF FEE & EASEMENT AREAS (ROUNDED) \$454,000

<u>c. SUMMARY OF REAL ESTATE ACQUISITION COSTS</u>	
Total Land Values	\$454,000
Severance Damages (Fee Estates)	85,000
Administrative Costs (74 Ownerships at \$1,200 Each)	88,800
Reservation Boundary Marking (13 Miles at \$2,000 Per Mile)	26,000
Contingencies (20% of Above)	130,760
Total Real Estate Costs	\$784,560
TOTAL REAL ESTATE COSTS (ROUNDED)	<u>\$780,000</u>

AREA H - MILLIS and MEDWAY, MASS.

ACQUISITION PLAN NO. 1 (Acquiring Entire Site - Excluding Existing Improvements)

- 1/ Land ownership data based on a study of Assessor's records and property maps.
- 2/ Includes the 16 acres of Municipal land owned by the Town of Millis.
- 3/ Easements recommended over low portion of lots (rear or side yards).
- 4/ Represents value of easements and damages resulting from easements.

AREA H - MILLIS and MEDWAY, MASS.

ACQUISITION PLAN NO. 2 (Excluding All Developed Lots and Potential Lots)

<u>Type of Ownerships</u>	<u>a. LAND OWNERSHIP 1/</u>		<u>Total Acres</u>	<u>No. of Owners</u>
	<u>Fee Acres</u>	<u>Easement Acres</u>		
Federal	--	--	--	--
State	--	--	--	--
Municipal	16	--	16	1
Private Conservation Soc.	--	--	--	--
Private	891	--	891	69
Totals	907	--	907	70

<u>Recommended Fee Estates</u>	<u>b. ESTIMATED LAND VALUES</u>		<u>Estimated Fair Market Value</u>
	<u>Average P/A Unit Value</u>	<u>Acres</u>	
Unimproved Industrial Land (Low - Rear)	\$500	60	\$ 30,000
Unimproved Industrial Land (Very Low & Wet)	300	142	42,600
Unimproved Land (Low)	500	100	50,000
Unimproved Land (Very Low & Wet)	300	605	181,500
Totals		907	\$304,100 2/

Recommended Easement Estates
None

TOTAL VALUE OF FEE AREA (ROUNDED)

\$304,000

c. SUMMARY OF REAL ESTATE ACQUISITION COSTS

Total Land Values	\$304,000
Severance Damages	75,000
Administrative Costs (70 Ownerships at \$1,200 Each)	84,000
Reservation Boundary Marking (13 Miles at \$2,000 Per Mile)	26,000
Contingencies (20% of Above)	97,800
Total Real Estate Costs	<u>\$586,800</u>

TOTAL REAL ESTATE COSTS (ROUNDED)

\$590,000

1/ Land ownership data based on a study of Assessor's records and property maps.

2/ Includes the 16 acres of Municipal land owned by the Town of Millis.

AREA I - SHERBORN, MASS.

ACQUISITION PLAN NO. 1 (Acquiring Entire Site - Excluding Existing Improvements)

<u>Type of Ownerships</u>	<u>a. LAND OWNERSHIP 1/</u>		<u>Total Acres</u>	<u>No. of Owners</u>
	<u>Fee Acres</u>	<u>Easement Acres</u>		
Federal	--	--	--	--
State	--	--	--	--
Municipal	--	--	--	--
Private Conservation Soc.	--	--	--	--
Private	280	35	315	27
Totals	280	35	315 2/	27

b. ESTIMATED LAND VALUES

<u>Recommended Fee Estates</u>	<u>Average P/A Unit Value</u>	<u>Acres</u>	<u>Estimated Fair Market Value</u>
Unimproved Land (Very Low & Wet)	\$ 700	220	\$154,000
Unimproved Land (Low)	1,200	60	72,000
Totals		280	226,000

<u>Recommended Easement Estates</u>	<u>Lots Subject To Easements 3/</u>	<u>Acres</u>	<u>Estimated Fair Market Value 4/</u>
Developed Residential Lots	7	5	\$ 14,000
Potential Residential Lots	22	30	100,000
Totals	29	35	\$114,000

<u>Total Lands</u>		315	\$340,000
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TOTAL VALUE OF FEE & EASEMENT AREAS (ROUNDED) \$340,000

c. SUMMARY OF REAL ESTATE ACQUISITION COSTS

Total Land Values	\$340,000
Severance Damages (Fee Estates)	60,000
Administrative Costs (27 Ownerships at \$1,200 Each)	32,400
Reservation Boundary Marking (5.0 Miles at \$2,000 Per Mile)	10,000
Contingencies (20% of Above)	88,480
Total Real Estate Costs	\$530,880

TOTAL REAL ESTATE COSTS (ROUNDED) \$530,000

- 1/ Land ownership data based on a study of Assessor's records and property maps.
 2/ Small portion of land zoned flood plain district (25' horizontal from streams and brooks).
 3/ Easements recommended over portions of lots (rear or side yards).
 4/ Represents value of easements and damages resulting from imposition of easements.

AREA I - SHERBORN, MASS.

ACQUISITION PLAN NO. 2 (Excluding All Developed Lots and Potential Lots)

<u>Type of Ownerships</u>	<u>a. LAND OWNERSHIP 1/</u>		<u>Total Acres</u>	<u>No. of Owners</u>
	<u>Fee Acres</u>	<u>Easement Acres</u>		
Federal	--	--	--	--
State	--	--	--	--
Municipal	--	--	--	--
Private Conservation Soc.	--	--	--	--
Private	280	--	280	17
Totals	280	--	280 2/	17

<u>b. ESTIMATED LAND VALUES</u>			
<u>Recommended Fee Estates</u>	<u>Average P/A</u>		<u>Estimated Fair Market Value</u>
	<u>Unit Value</u>	<u>Acres</u>	
Unimproved Land (Very Low & Wet)	\$ 700	220	\$154,000
Unimproved Land (Low)	1,200	60	72,000
		280	\$226,000

Recommended Easement Estates
None

TOTAL VALUE OF FEE AREA (ROUNDED)

\$226,000

c. SUMMARY OF REAL ESTATE ACQUISITION COSTS

Total Land Values	\$226,000
Severance Damages	60,000
Administrative Costs (17 Ownerships at \$1,200 Each)	20,400
Reservation Boundary Marking (5.0 Miles at \$2,000 Per Mile)	10,000
Contingencies (20% of Above)	63,280
Total Real Estate Costs	<u>\$379,680</u>

TOTAL REAL ESTATE COSTS (ROUNDED)

\$380,000

- 1/ Land ownership data based on a study of Assessor's records and property maps.
 2/ Small portion of land zoned flood plain district (25' horizontal from streams and brooks).

AREA J - HOLLISTON and SHERBORN, MASS.

ACQUISITION PLAN (Acquiring Entire Site - Excluding Existing Improvements)

<u>Type of Ownerships</u>	<u>a. LAND OWNERSHIP 1/</u>		<u>Total Acres</u>	<u>No. of Owners</u>
	<u>Fee Acres</u>	<u>Easement Acres</u>		
Federal	--	--	--	--
State	--	--	--	--
Municipal	3	--	3	1
Private Conservation Soc.	--	--	--	--
Private	127	--	127	11
Totals	130	--	130 2/	12

<u>Recommended Fee Estates</u>	<u>b. ESTIMATED LAND VALUES</u>		<u>Estimated Fair Market Value</u>
	<u>Average P/A Unit Value</u>	<u>Acres</u>	
Unimproved Industrial Land (Low)	\$1,000	8	\$ 8,000
Unimproved Land (Very Low & Wet)	300	92	27,600
Unimproved Land (Low)	500	30	15,000
Totals		130	\$50,600 3/

Recommended Easement Estates
None

TOTAL VALUE OF FEE AREA (ROUNDED) \$51,000

<u>c. SUMMARY OF REAL ESTATE ACQUISITION COSTS</u>	
Total Land Values	\$ 51,000
Severance Damages	17,000
Administrative Costs (12 Ownerships at \$1,200 Each)	14,400
Reservation Boundary Marking (2.2 Miles at \$2,000 Per Mile)	4,400
Contingencies (20% of above)	17,360
Total Real Estate Costs	<u>\$104,160</u>

TOTAL REAL ESTATE COSTS (ROUNDED) \$100,000

- 1/ Land ownership data based on a study of Assessor's records and property maps.
 2/ A small portion of the land in Sherborn is zoned as a flood plain district (25' horizontal from streams and brooks).
 3/ Includes 3 acres of Municipally-owned land.

AREA K - NORFOLK, MASS.

ACQUISITION PLAN NO. 1 (Acquiring Entire Site - Excluding Existing Improvements)

<u>Type of Ownerships</u>	<u>a. LAND OWNERSHIP 1/</u>		<u>Total Acres</u>	<u>No. of Owners</u>
	<u>Fee Acres</u>	<u>Easement Acres</u>		
Federal	--	--	--	--
State	390	--	390	1
Municipal	--	--	--	--
Private Conservation Soc.	--	--	--	--
Private	9	1	10	2
Totals	399	1	400	3

<u>Recommended Fee Estates 2/</u>	<u>b. ESTIMATED LAND VALUES</u>		<u>Estimated Fair Market Value</u>
	<u>Average P/A Unit Value</u>	<u>Acres</u>	
Unimproved Industrial Land (Low - Front)	\$3,000	4	\$ 12,000
Unimproved Industrial Land (Low - Rear)	1,000	5	5,000
Unimproved Land (Very Low & Wet)	300	320	96,000
Unimproved Land (Low)	500	70	35,000
Totals		399	\$148,000 3/

<u>Recommended Easement Estates</u>	<u>Lots Subject To Easements 4/</u>	<u>Acres</u>	<u>Estimated Fair Market Value 5/</u>
Developed Commercial Lot	1	1	\$ 4,000
<u>Total Lands</u>		400	\$152,000

TOTAL VALUE OF FEE & EASEMENT AREAS (ROUNDED) \$152,000

<u>c. SUMMARY OF REAL ESTATE ACQUISITION COSTS</u>	
Total Land Values	\$152,000
Severance Damages (Fee Estates)	35,000
Administrative Costs (3 Ownerships at \$1,200 Each)	3,600
Reservation Boundary Marking (5.6 Miles at \$2,000 Per Mile)	11,200
Contingencies (20% of Above)	40,360
Total Real Estate Costs	\$242,160
TOTAL REAL ESTATE COSTS (ROUNDED)	<u>\$240,000</u>

- 1/ Land ownership data based on a study of Assessor's records and property maps.
2/ It is assumed that the proposed acquisition will not include any productive agricultural land. If it is later found that the taking of productive farm land will be required from the State Correction Department property, it is recommended that easements be acquired in lieu of fee over the agricultural land, in order that it may continue to be used for agricultural purposes.
3/ Includes the 390 acres of land owned by the State Correction Department.
4/ Easement recommended over low portion of one commercially developed lot.
5/ Represents value of easement and damage resulting from imposition of easement.

AREA K - NORFOLK, MASS.

ACQUISITION PLAN NO. 2 (Excluding All Developed Lots and Potential Lots)

Type of Ownerships	a. LAND OWNERSHIP 1/		Total Acres	No. of Owners
	Fee Acres	Easement Acres		
Federal	--	--	--	--
State	390	--	390	1
Municipal	--	--	--	--
Private Conservation Soc.	--	--	--	--
Private	5	--	5	1
Totals	395	--	395	2

Recommended Fee Estates 2/	b. ESTIMATED LAND VALUES		Estimated Fair Market Value
	Average P/A Unit Value	Acres	
Unimproved Industrial Land (Low - Rear)	\$1,000	5	\$ 5,000
Unimproved Land (Very Low & Wet)	300	320	96,000
Unimproved Land (Low)	500	70	35,000
Totals		395	\$136,000 3/

Recommended Easement Estates
None

TOTAL VALUE OF FEE AREA (ROUNDED)

\$136,000

c. SUMMARY OF REAL ESTATE ACQUISITION COSTS

Total Land Values	\$136,000
Severance Damages	35,000
Administrative Costs (2 Ownerships at \$1,200 Each)	2,400
Reservation Boundary Marking (5.6 Miles at \$2,000 Per Mile)	11,200
Contingencies (20% of Above)	36,920
Total Real Estate Costs	\$221,520

TOTAL REAL ESTATE COSTS (ROUNDED)

\$220,000

- 1/ Land ownership data based on a study of Assessor's records and property maps.
 2/ It is assumed that the proposed acquisition will not include any productive agricultural land. If it is later found that the taking of productive farm land will be required from the State Correction Department property, it is recommended that easements be acquired in lieu of fee over the agricultural land in order that it may continue to be used for agricultural purposes.
 3/ Includes the 390 acres of land owned by the State Correction Department.

AREA L - NORFOLK, MASS.

ACQUISITION PLAN (Acquiring Entire Site - Excluding Existing Improvements)

<u>Type of Ownerships</u>	<u>a. LAND OWNERSHIP 1/</u>		<u>Total Acres</u>	<u>No. of Owners</u>
	<u>Fee Acres</u>	<u>Easement Acres</u>		
Federal	--	--	--	--
State	--	--	--	--
Municipal	--	--	--	--
Private Conservation Soc.	--	--	--	--
Private	<u>359</u>	<u>1</u>	<u>360</u>	<u>16</u>
Totals	<u>359</u>	<u>1</u>	<u>360</u>	<u>2/ 16</u>

<u>b. ESTIMATED LAND VALUES</u>			
<u>Recommended Fee Estates 3/</u>	<u>Average P/A</u>		<u>Estimated Fair Market Value</u>
	<u>Unit Value</u>	<u>Acres</u>	
Unimproved Land (Very Low & Wet)	\$300	<u>289</u>	\$ 86,700
Unimproved Land (Low)	500	<u>70</u>	35,000
		<u>359</u>	<u>\$121,700</u>
<u>Recommended Easement Estates</u>	<u>Lots Subject</u>		<u>Estimated Fair Market Value 5/</u>
	<u>To Easements 4/</u>	<u>Acres</u>	
Developed Residential Lots	3	<u>1</u>	\$ 3,000
<u>Total Lands</u>		<u>360</u>	<u>\$124,700</u>

TOTAL VALUE OF FEE & EASEMENT AREAS (ROUNDED) \$125,000

<u>c. SUMMARY OF REAL ESTATE ACQUISITION COSTS</u>	
Total Land Values	\$125,000
Severance Damages (Fee Estates)	35,000
Administrative Costs (16 Ownerships at \$1,200 Each)	19,200
Reservation Boundary Marking (4.7 Miles at \$2,000 Per Mile)	9,400
Contingencies (20% of Above)	37,720
Total Real Estate Costs	<u>\$226,320</u>
TOTAL REAL ESTATE COSTS (ROUNDED)	<u>\$230,000</u>

- 1/ Land ownership data based on a study of Assessor's records and property maps.
 2/ Entire site flood plain zoned.
 3/ It is assumed that the improved Norfolk Airport runway area will not be included in the taking area.
 4/ Easements recommended over low portions of lots (rear or side yards).
 5/ Represents value of easements and damages resulting from imposition of easements.

AREA M - FRANKLIN, MASS.

ACQUISITION PLAN NO. 1 (Acquiring Entire Site - Excluding Existing Improvements)

<u>Type of Ownerships</u>	<u>a. LAND OWNERSHIP 1/</u>		<u>Total Acres</u>	<u>No. of Owners</u>
	<u>Fee Acres</u>	<u>Easement Acres</u>		
Federal	--	--	--	--
State	--	--	--	--
Municipal	2	--	2	1
Private Conservation Soc.	---	--	---	---
Private	<u>393</u>	<u>5</u>	<u>398</u>	<u>54</u>
Totals	<u>395</u>	<u>5</u>	<u>400</u>	<u>55</u>

<u>Recommended Fee Estates</u>	<u>b. ESTIMATED LAND VALUES</u>		<u>Estimated Fair Market Value</u>
	<u>Average P/A Unit Value</u>	<u>Acres</u>	
Unimproved Industrial Land	\$1,000	100	\$100,000
Unimproved Industrial Land (Very Low & Wet)	300	115	34,500
Unimproved Land (Low)	500	35	17,500
Unimproved Land (Very Low & Wet)	300	<u>145</u>	<u>43,500</u>
Totals		<u>395</u>	<u>\$195,500</u>

<u>Recommended Easement Estates</u>	<u>Lots Subject To Easements 4/</u>	<u>Acres</u>	<u>Estimated Fair Market Value 5/</u>
Developed Residential Lots	35	5	\$ 70,000
<u>Total Lands</u>		<u>400</u>	<u>\$265,500</u>

TOTAL VALUE OF FEE & EASEMENT AREAS (ROUNDED) \$266,000

<u>c. SUMMARY OF REAL ESTATE ACQUISITION COSTS</u>	
Total Land Values	\$266,000
Severance Damages (Fee Estates)	50,000
Administrative Costs (55 Ownerships at \$1,200 Each)	66,000
Reservation Boundary Marking (10 Miles at \$2,000 Per Mile)	20,000
Contingencies (20% of Above)	<u>80,400</u>
Total Real Estate Costs	<u>\$482,400</u>
TOTAL REAL ESTATE COSTS (ROUNDED)	<u>\$480,000</u>

- 1/ Land ownership data based on a study of Assessor's records and property maps.
- 2/ Entire site flood plain zoned.
- 3/ Includes the 2 acres of Municipally-owned land; estimate does not include purchase of Municipal sewerage facilities.
- 4/ Easements recommended over low portions of lots (rear or side yards).
- 5/ Represents value of easements and damages resulting from imposition of easements.

AREA M - FRANKLIN, MASS.

ACQUISITION PLAN NO. 2 (Excluding All Developed Lots and Potential Lots)

<u>Type of Ownerships</u>	<u>a. LAND OWNERSHIP 1/</u>		<u>Total Acres</u>	<u>No. of Owners</u>
	<u>Fee Acres</u>	<u>Easement Acres</u>		
Federal	--	--	--	--
State	--	--	--	--
Municipal	2	--	2	1
Private Conservation Soc.	--	--	--	--
Private	<u>393</u>	--	<u>393</u>	<u>19</u>
Totals	<u>395</u>	--	<u>395</u> 2/	<u>20</u>

<u>Recommended Fee Estates</u>	<u>b. ESTIMATED LAND VALUES</u>		<u>Estimated Fair Market Value</u>
	<u>Average P/A Unit Value</u>	<u>Acres</u>	
Unimproved Industrial Land	\$1,000	100	\$100,000
Unimproved Industrial Land (Very Low & Wet)	300	115	34,500
Unimproved Land (Low)	500	35	17,500
Unimproved Land (Very Low & Wet)	300	<u>145</u>	<u>43,500</u> 3/
Totals		<u>395</u>	<u>\$195,500</u>

Recommended Easement Estates
None

TOTAL VALUE OF FEE AREA (ROUNDED) \$196,000

<u>c. SUMMARY OF REAL ESTATE ACQUISITION COSTS</u>	
Total Land Values	\$196,000
Severance Damages	50,000
Administrative Costs (20 Ownerships at \$1,200 Each)	24,000
Reservation Boundary Marking (10 Miles at \$2,000 Per Mile)	20,000
Contingencies (20% of Above)	58,000
Total Real Estate Costs	<u>\$348,000</u>
TOTAL REAL ESTATE COSTS (ROUNDED)	<u>\$350,000</u>

- 1/ Land ownership data based on a study of Assessor's records and property maps.
 2/ Entire site flood plain zoned.
 3/ Includes the 2 acres of Municipally-owned land.

AREA N - FRANKLIN, MASS.

ACQUISITION PLAN (Acquiring Entire Site - Excluding Existing Improvements)

<u>Type of Ownerships</u>	<u>a. LAND OWNERSHIP 1/</u>		<u>Total Acres</u>	<u>No. of Owners</u>
	<u>Fee Acres</u>	<u>Easement Acres</u>		
Federal	--	--	--	--
State	--	--	--	--
Municipal	5	--	5	1
Private Conservation Soc.	--	--	--	--
Private	145	--	145	13
Totals	150	--	150 2/	14

<u>Recommended Fee Estates</u>	<u>b. ESTIMATED LAND VALUES</u>		<u>Estimated Fair Market Value</u>
	<u>Average P/A Unit Value</u>	<u>Acres</u>	
Unimproved Industrial Land (Low)	\$1,000	50	\$ 50,000
Unimproved Industrial Land (Very Low & Wet)	300	100	30,000 3/
Totals		150	\$ 80,000 4/

Recommended Easement Estates
None

TOTAL VALUE OF FEE AREA (ROUNDED) \$ 80,000

<u>c. SUMMARY OF REAL ESTATE ACQUISITION COSTS</u>	
Total Land Values	\$ 80,000
Severance Damages	30,000
Administrative Costs (14 Ownerships at \$1,200 Each)	16,800
Reservation Boundary Marking (4.2 Miles at \$2,000 Per Mile)	8,400
Contingencies (20% of Above)	27,040
Total Real Estate Costs	\$162,240
TOTAL REAL ESTATE COSTS (ROUNDED)	\$ <u>160,000</u>

- 1/ Land ownership data based on a study of Assessor's records and property maps.
 2/ Entire site flood plain zoned.
 3/ Includes the 5 acres of Municipally-owned land.
 4/ Land value estimate does not include purchase of Municipal water facilities.

AREA 0 - FRANKLIN and WRENTHAM, MASS.

ACQUISITION PLAN NO. 1 (Acquiring Entire Site - Excluding Existing Improvements)

<u>Type of Ownerships</u>	<u>a. LAND OWNERSHIP 1/</u>		<u>Total Acres</u>	<u>No. of Owners</u>
	<u>Fee Acres</u>	<u>Easement Acres</u>		
Federal	--	--	--	--
State	114	--	114	1
Municipal	--	--	--	--
Private Conservation Soc.	--	--	--	--
Private	161	--	161	25
Totals	<u>275</u>	<u>--</u>	<u>275</u> 2/	<u>26</u>

<u>Recommended Fee Estates</u>	<u>b. ESTIMATED LAND VALUES</u>		<u>Estimated Fair Market Value</u>
	<u>Average P/A Unit Value</u>	<u>Acres</u>	
Unimproved Land (Low)	\$500	50	\$ 25,000
Unimproved Land (Very Low & Wet)	300	216	64,800
Totals		<u>266</u>	<u>\$ 89,800</u>

<u>Recommended Easement Estates</u>	<u>Lots Subject To Easements 3/</u>	<u>Acres</u>	<u>Estimated Fair Market Value 4/</u>
Potential Residential Lots	15	9	\$ 30,000
<u>Total Lands</u>		<u>275</u>	<u>\$119,800 5/</u>

TOTAL VALUE OF FEE & EASEMENT AREAS (ROUNDED) \$120,000

<u>c. SUMMARY OF REAL ESTATE ACQUISITION COSTS</u>	
Total Land Values	\$120,000
Severance Damages (Fee Estates)	35,000
Administrative Costs (26 Ownerships at \$1,200 Each)	31,200
Reservation Boundary Marking (6.3 Miles at \$2,000 Per Mile)	12,600
Contingencies (20% of Above)	39,760
Total Real Estate Costs	<u>\$238,560</u>
TOTAL REAL ESTATE COSTS (ROUNDED)	
	<u>\$240,000</u>

- 1/ Land ownership data based on a study of Assessor's records and property maps.
 2/ Land in Franklin flood plain zoned.
 3/ Easements recommended over low portions of lots (rear or side yards).
 4/ Represents value of easements and damages resulting from imposition of easements.
 5/ Includes the 114 acres of State-owned land.

AREA 0 - FRANKLIN and WRENTHAM, MASS.

ACQUISITION PLAN NO. 2 (Excluding All Developed Lots and Potential Lots)

<u>Type of Ownerships</u>	<u>a. LAND OWNERSHIP 1/</u>		<u>Total Acres</u>	<u>No. of Owners</u>
	<u>Fee Acres</u>	<u>Easement Acres</u>		
Federal	--	--	--	--
State	105	--	105	1
Municipal	--	--	--	--
Private Conservation Soc.	--	--	--	--
Private	161	--	161	25
Totals	266	--	266 2/	26

<u>Recommended Fee Estates</u>	<u>b. ESTIMATED LAND VALUES</u>		<u>Estimated Fair Market Value</u>
	<u>Average P/A Unit Value</u>	<u>Acres</u>	
Unimproved Land (Low)	\$500	50	\$ 25,000
Unimproved Land (Very Low & Wet)	300	216	64,800
Totals		266	\$ 89,800 3/

Recommended Easement Estates
None

TOTAL VALUE OF FEE AREA (ROUNDED) \$ 90,000

<u>c. SUMMARY OF REAL ESTATE ACQUISITION COSTS</u>	
Total Land Values	\$ 90,000
Severance Damages	35,000
Administrative Costs (26 Ownerships at \$1,200 Each)	31,200
Reservation Boundary Marking (6.3 Miles at \$2,000 Per Mile)	12,600
Contingencies (20% of Above)	33,760
Total Real Estate Costs	\$202,560
TOTAL REAL ESTATE COSTS (ROUNDED)	\$ <u>200,000</u>

1/ Land ownership data based on a study of Assessor's records and property maps.

2/ Land in Franklin flood plain zoned.

3/ Includes the 105 acres of State-owned land.

AREA P - HOLLISTON and MEDWAY, MASS.

ACQUISITION PLAN NO. 1 (Acquiring Entire Site - Excluding Existing Improvements)

<u>Type of Ownerships</u>	<u>a. LAND OWNERSHIP 1/</u>		<u>Total Acres</u>	<u>No. of Owners</u>
	<u>Fee Acres</u>	<u>Easement Acres</u>		
Federal	--	--	--	--
State	--	--	--	--
Municipal	80	--	80	1
Private Conservation Soc.	--	--	--	--
Private	624	31	655	134
Totals	704	31	735	135

<u>Recommended Fee Estates</u>	<u>b. ESTIMATED LAND VALUES</u>		<u>Estimated Fair Market Value</u>
	<u>Average P/A Unit Value</u>	<u>Acres</u>	
Unimproved Industrial Land	\$1,000	40	\$ 40,000
Unimproved Industrial Land (Very Low & Wet)	300	60	18,000
Unimproved Land (Low)	500	100	50,000
Unimproved Land (Very Low & Wet)	300	504	151,200
Totals		704	\$259,200 ± 3/

<u>Recommended Easement Estates</u>	<u>Lots Subject To Easements 4/</u>		<u>Estimated Fair Market Value 5/</u>
	<u>To Easements 4/</u>	<u>Acres</u>	
Developed Residential Lots	70	20	\$1-0,000
Potential Residential Lots	16	11	32,000
Totals	86	31	\$172,000

<u>Total Lands</u>	735	\$431,200
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TOTAL VALUE OF FEE & EASEMENT AREAS (ROUNDED) \$431,000

c. SUMMARY OF REAL ESTATE ACQUISITION COSTS

Total Land Values	\$431,000
Severance Damages (Fee Estates)	60,000
Administrative Costs (135 Ownerships at \$1,200 Each)	162,000
Reservation Boundary Marking (17.6 Miles at \$2,000 Per Mile)	35,200
Contingencies (20% of Above)	141,540
Total Real Estate Costs	\$849,540

TOTAL REAL ESTATE COSTS (ROUNDED) \$850,000

- 1/ Land ownership data based on a study of Assessor's records and property maps.
- 2/ Includes the 80 acres of Municipal land owned by the Town of Holliston.
- 3/ Land value estimate does not include purchase of Holliston town dump.
- 4/ Easements recommended over low portions of lots (rear or side yards).
- 5/ Represents value of easements and damages resulting from imposition of easements.

AREA P - HOLLISTON and MEDWAY, MASS.

ACQUISITION PLAN NO. 2 (Excluding All Developed Lots and Potential Lots)

<u>Type of Ownerships</u>	<u>a. LAND OWNERSHIP 1/</u>		<u>Total Acres</u>	<u>No. of Owners</u>
	<u>Fee Acres</u>	<u>Easement Acres</u>		
Federal	--	--	--	--
State	--	--	--	--
Municipal	80	--	80	1
Private Conservation Soc.	--	--	--	--
Private	624	--	624	67
Totals	<u>704</u>	<u>--</u>	<u>704</u>	<u>68</u>

<u>Recommended Fee Estates</u>	<u>b. ESTIMATED LAND VALUES</u>		<u>Estimated Fair Market Value</u>	
	<u>Average P/A Unit Value</u>	<u>Acres</u>		
Unimproved Industrial Land	\$1,000	40	\$ 40,000	
Unimproved Industrial Land (Very Low & Wet)	300	60	18,000	
Unimproved Land (Low)	500	100	50,000	
Unimproved Land (Very Low & Wet)	300	504	151,200	
Totals		<u>704</u>	<u>\$259,200</u>	2/ 3/

Recommended Easement Estates
None

TOTAL VALUE OF FEE AREA (ROUNDED) \$259,000

<u>c. SUMMARY OF REAL ESTATE ACQUISITION COSTS</u>	
Total Land Values	\$259,000
Severance Damages	80,000
Administrative Costs (68 Ownerships at \$1,200 Each)	81,600
Reservation Boundary Marking (17.6 Miles at \$2,000 Per Mile)	35,200
Contingencies (20% of Above)	<u>91,160</u>
Total Real Estate Costs	<u>\$546,960</u>
TOTAL REAL ESTATE COSTS (ROUNDED)	<u>\$550,000</u>

- 1/ Land ownership data based on a study of Assessor's records and property maps.
 2/ Includes the 80 acres of Municipal land owned by the Town of Holliston.
 3/ Land value estimate does not include purchase of Holliston town dump.

AREA R - BELLINGHAM, MASS.

ACQUISITION PLAN (Acquiring Entire Site - Excluding Existing Improvements)

<u>Type of Ownerships</u>	<u>a. LAND OWNERSHIP 1/</u>		<u>Total Acres</u>	<u>No. of Owners</u>
	<u>Fee Acres</u>	<u>Easement Acres</u>		
Federal	--	--	--	--
State	--	--	--	--
Municipal	15	--	15	1
Private Conservation Soc.	--	--	--	--
Private	165	--	165	12
Totals	180	--	180	13

<u>Recommended Fee Estates</u>	<u>b. ESTIMATED LAND VALUES</u>		<u>Estimated Fair Market Value</u>
	<u>Average P/A Unit Value</u>	<u>Acres</u>	
Unimproved Industrial Land	\$1,000	70	\$ 70,000
Unimproved Industrial Land (Very Low & Wet)	500	70	35,000
Unimproved Land	300	40	12,000
Totals		180	\$117,000 3/

Recommended Easement Estates
None

TOTAL VALUE OF FEE AREA (ROUNDED) \$117,000

<u>c. SUMMARY OF REAL ESTATE ACQUISITION COSTS</u>	
Total Land Values	\$117,000
Severance Damages	40,000
Administrative Costs (13 Ownerships at \$1,200 Each)	15,600
Reservation Boundary Marking (4.8 Miles at \$2,000 Per Mile)	9,600
Contingencies (20% of Above)	36,440
Total Real Estate Costs	\$218,640
TOTAL REAL ESTATE COSTS (ROUNDED)	<u>\$220,000</u>

1/ No Assessor's property maps available at time of estimate - land ownership data based on general information provided by local Town Officials.

2/ Includes the 15 acres of Municipally-owned land; land value estimate does not include purchase of community well field located within this site.

AREA S - BELLINGHAM, MASS.

ACQUISITION PLAN (Acquiring Entire Site - Excluding Existing Improvements)

<u>Type of Ownerships</u>	<u>a. LAND OWNERSHIP 1/</u>		<u>Total Acres</u>	<u>No. of Owners</u>
	<u>Fee Acres</u>	<u>Easement Acres</u>		
Federal	--	--	--	--
State	--	--	--	--
Municipal	--	--	--	--
Private Conservation Soc.	--	--	--	--
Private	400	--	400	20
Totals	400	--	400 2/	20

<u>Recommended Fee Estates</u>	<u>b. ESTIMATED LAND VALUES</u>		<u>Estimated Fair Market Value</u>
	<u>Average P/A Unit Value</u>	<u>Acres</u>	
Unimproved Industrial Land	\$1,000	100	\$100,000
Unimproved Industrial Land (Very Low & Wet)	300	150	45,000
Unimproved Land (Low)	500	30	15,000
Unimproved Land (Very Low & Wet)	300	120	36,000
Totals		400	\$196,000

Recommended Easement Estates
None

TOTAL VALUE OF FEE AREA (ROUNDED) \$196,000

c. SUMMARY OF REAL ESTATE ACQUISITION COSTS

Total Land Values	\$196,000
Severance Damages	55,000
Administrative Costs (20 Ownerships at \$1,200 Each)	24,000
Reservation Boundary Marking (9.5 Miles at \$2,000 Per Mile)	19,000
Contingencies (20% of Above)	58,800
Total Real Estate Costs	\$352,800

TOTAL REAL ESTATE COSTS (ROUNDED) \$350,000

1/ No Assessor's property maps available at time of estimate - land ownership data based on general information provided by local Town Officials.

2/ Majority of site is flood plain zoned.

ATTACHMENT HB

CANOE LAUNCH SITES

CANOE LAUNCH SITES

The spring with its higher flows is generally the most favorable period for canoeing the upper Charles River. In summer and fall canoes will strike underwater obstructions in many sections when the water is low. However, an alert canoe team need have no worries since these can usually be spotted in time. It is hoped that the following table of access sites and other information will be useful to people who enjoy canoeing and may become the basis for more use of this beautiful river by canoe, the best method of seeing and enjoying the middle and upper Charles River.

The lower Charles Basin, an 8.4 mile protected water body between Galen Street, Watertown and Charles River Dam in Boston, is not ordinarily open to canoeists. This is often subject to high winds and there are many traffic problems due to power boats in the basin. For these reasons the Metropolitan District Commission, which has the responsibility in this area does not encourage the use of canoes in the basin.

TABLE HB-I

UPPER CHARLES RIVER CANOE TRIPS

Access Site Location	Condition of Site	Public/Private Land * ROW-Right of way.	Distance from last site in river miles	Recommendations
(1) Populatic St. bridge Medway, right bank upstream of bridge.	Good	Not known		Level land. Should be acquired if necessary, 3-car-off street parking suggested.
(2) Populatic Pond, Medway.	No public access.	Private	1.18	Public access needed. Suggest west shore site. Heavy development on shores.
(3) Mill River/Charles River, Millis/Norfolk, River Road	Excellent	Probably highway ROW*	1.19	Limited parking and hard-top ramp available. More parking needed.
(4) Pleasant St. upstream right bank, Millis/Norfolk	Poor	Not known	.74	Remains of old dam block river and should be cleared. Site should be acquired & graded from bridge level on both sides.
(5) Baltimore St. (Rte 115) Millis/Norfolk	None	Not known	.84	Land near bridge has poten- tial. Further investigation.
(6) Forest Rd. Bridge, Millis/ Medfield	Two good sites	Probably town ROW	1.56	One site upstream and one downstream. No further recommendations.
(7) Stop River, Medfield, Causeway St. bridge	Excellent	Probably highway ROW	2.70	Very convenient to tributary which leads into Charles R.
(8) Rte 109 Bridge, Millis/ Medfield. Downstream right bank.	Good	Probably highway ROW	.78	Steep but very suitable with minimum work-grading & 6-car off highway parking space.
(9) Bridge St. Millis/ Medfield. Left.	Good	Not known	1.09	If not public, should be acquired. Minimum work - 3 car parking.

TABLE HB-I UPPER CHARLES RIVER CANOE TRIPS (Contd)

Access Site Location	Condition of Site	Public/Private Land	Distance from last site in river miles.	Recommendations
		* ROW - Right of way		
(10) Rte 27 Bridge Medfield/Sherborn, upstream, right	Steep terrain.	Probably highway ROW*	2.69	Should be acquired, if needed. Grading & off street parking- 3 cars.
(11) Rocky Narrows, left. Sherborn.	Excellent.	Trustees of Reservations	1.27	Access by canoe only. Fine stopping place.
(12) Farm Road Bridge, Dover. Downstream right bank.	Excellent.	Town of Dover.	1.44	None. Ample parking space available. An easy launching area.
(13) South Natick Dam, upstream, right.	Excellent.	Town of Natick	3.58	Existing town park contains good flat bank for landing or launching.
(14) South Natick Dam, downstream, right.	Poor.	Town of Natick Total miles from Medway	19.06	Steep and overgrown. No off street parking. Needs grading and clearing.
(15) Needham Town Forest, off Charles River St. left bank.	Good	Town of Needham	2.96	Town plan calls for recreational use of this area. Excellent access sites, and roads already available.
(16) Central Ave., Dover/Needham	None available.	Not known	2.51	Areas with good potential near bridge. Further investigation.
(17) Charles River Peninsula, Needham, left.	Potentially good.	Trustees of Reservations	.97	Access Road is available. Much of land is suitable for launching facilities.
(18) Redwing Bay, upstream left bank, of Cochrane Dam.	Excellent	Private	.05	Area operated by YMCA with a canoe rental livery and good launching facilities.

TABLE HB-I UPPER CHARLES RIVER CANOE TRIPS (Contd)

Access Site Location	Condition of Site	Public/Private Land	Distance from last site in river miles	Recommendations
* ROW - Right of Way				
(19) Cochrane Dam, Dover, Downstream, right bank.	Fair	Probably town-owned, in highway ROW.	.03	Launching only. Need high water. Many large rocks in river.
(20) Chestnut St. Bridge, Dover/Needham	No Access available.	Not known.	1.57	Good potential. Further investigation
(21) South St. Needham, downstream Rte 135, left bank.	Excellent.	Town of Needham	1.58	Good Access, parking and launching. No further recommendations.
(22) Old Great Plain Rd., Needham, downstream of Rte 128, left bank.	Excellent.	Town of Needham.	.94	This site is ideal, except for its perpetual and unsupervised misuses by public for parking and littering. Contains a ramp and ample parking. Needs restoration and supervision.
(23) Havey Beach, Dedham., left bank.	None available.	M.D.C.	5.24	Day use area, with tennis courts & playgrounds. Site has potential, although MDC has a launching site near its rink on other bank further downstream.
(24) Kendrick St. Bridge, Needham. Left bank, downstream.	Good potential.	Perhaps M.D.C.	3.19	Investigate ownership. Potential for major access facility here. Ample space for parking. Acquisition if needed.

TABLE HB-I UPPER CHARLES RIVER CANOE TRIPS (Contd)

Access Site Location	Condition of Site	Public/Private Land	Distance from last site in river miles	Recommendations
(25) Hemlock Gorge Reservation. Left bank, upstream of Silk Mill Dam, Newton Upper Falls.	Excellent	M.D.C. Total miles..... From South Natick Dam	1.84 <u>20.88</u>	Now used by canoeists. More parking space needed. This is lower end of this section of river.
(26) Quinobequin Road, Newton. Right bank, * distance downstream of Rte 9.	Excellent	M.D.C.	.75 *	Easy parking and access available at several locations off this road.
(27) Cordingley Dam, Newton. Upstream, left bank, ** distance from Rte 9.	Fair	Not known Total distance of this section.	1.74 **	A private conservation group has suggested restoring this as a historical site. Land should be acquired. Old bridge is hazardous in present condition.
(28) Leo J. Martin Memorial Golf Course. Weston/Wellesley. *** distance from Newton Lower Falls.	Several potential sites.	Public. M.D.C. and Town of Weston	1.00 ***	Minimum work needed. Suitable sites are numerous.
(29) Riverside Recreation Grounds., downstream of Rte. 128, left bank.	Excellent.	M.D.C.	.80	Existing ramp, parking and access are available and excellent. MDC is reported to be planning a restoration project.
(30) Norumbega, Duck Feeding Area, Downstream of Rte 30, left bank.	Excellent potential.	M.D.C.	.75	With minimum work this area could be utilized by canoeists. Major size parking is available now.

TABLE HB-I UPPER CHARLES RIVER CANOE TRIPS (Contd)

Access Site Location	Condition of Site	Public/Private Land	Distance from last site in river miles.	Recommendations
(31) Woerd Avenue, Waltham. Right bank.	Good potential.	M.D.C.	.73	Good potential for canoe access and landing. Parking and access now available. Area needs policing and restoration. Bad litter problem.
(32) Moody Street, Waltham. Upstream, right bank.	Good.	M.D.C. Total miles from Newton Lower Falls.	$\frac{2.03}{5.31}$	Serviceable dock is available. This is the downstream end of the canoe routes.

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